CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter details the market and technology assessment that the U.S. Department of Energy (DOE) has conducted in support of the energy conservation standards rulemaking for residential water heaters, direct heating equipment, and pool heaters.

This chapter consists of the market assessment and the technology assessment. The goal of the market assessment is to develop a qualitative and quantitative characterization of the residential water heater, direct heating equipment, and pool heater industries and market structures based on publicly available information and data and other information that DOE received directly from manufacturers and other interested parties. DOE examined publicly available information from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment certification directory, as well as U.S. Census Bureau Current Industrial Reports (CIR) and Annual Survey of Manufacturers (ASM), the appliance database from the California Energy Commission (CEC), and information from the Federal Trade Commission (FTC). The market and technology assessment addresses manufacturer characteristics and market shares, existing regulatory and non-regulatory efficiency improvement initiatives, product classes, and trends in product markets and characteristics. DOE performs the technology assessment to develop a preliminary list of technologies (referred to as technology options) that could be used to improve the efficiency of residential water heaters, direct heating equipment, and pool heaters.

3.1.1 Description of Products

Residential water heaters primarily provide hot water to residences for consumer use, appliances, and other functions. Some residential water heaters may also provide heated water to radiant heating systems. A basic gas storage residential water heater is comprised of a standing pilot ignition system, a burner, a combustion chamber, a flue baffle, a flue, an insulated water tank, a cold water inlet and hot water outlet, a sacrificial anode rod, a gas valve, a temperature and pressure relief valve, a thermostat, heat traps, and an outer case. A basic electric storage residential water heater is comprised of an electric resistance heating element, a sacrificial anode, an insulated water tank, a cold water inlet and a hot water outlet, a temperature and pressure relief valve, a thermostat with wire harness, heat traps, and an outer case. A basic oil storage residential water heater is comprised of a combustion chamber, a flue baffle, a flue, an insulated water tank, a cold water inlet and hot water outlet, a sacrificial anode, a power burner system, a thermostat, a temperature and pressure relief valve, and an outer case. A basic gas instantaneous residential water heater is comprised of a combustion chamber, a burner, a heat exchanger, a vent, a cold water inlet and hot water outlet, a gas valve, a standing pilot ignition system, a burner control thermostat, a flow detector, and an outer case.

In the United States, 99.9 percent (110 million) of homes have water heaters (as of 2005). Energy consumption attributable to water heater operation represents 1.7 percent (1.68 quads) of total U.S. energy consumption. Within individual homes, water heating represents, on average, 17 percent of total annual household energy consumption.[1]

Direct heating equipment (DHE) typically provides primary or supplemental space heating within a single room in a building. Some direct heating equipment, particularly gas hearth DHE, serve an aesthetic purpose in addition to being used for space heating. A basic residential gas wall fan-type heater consists of an outer case, an air circulation fan, a burner, a combustion chamber/heat exchanger, a standing pilot ignition system, a pilot light sensing control valve, a flue, a draft diverter, an air intake, and a burner control thermostat. A basic residential gas wall gravity-type heater consists of an outer case, a burner, a combustion chamber/heat exchanger, a standing pilot ignition system, a pilot light sensing control valve, a flue, a draft diverter, an air intake, and a burner control thermostat. Gravity provides air circulation as warm air rises (*i.e.*, warm air, which is less dense, rises and cool air, which is more dense, descends due to buoyancy effects). A basic residential gas floor heater consists of an outer case, a burner, a combustion chamber/heat exchanger, a standing pilot ignition system, a pilot light sensing control valve, a flue, a draft hood, an air intake, a burner control thermostat, and a floor grate. A basic residential gas room heater consists of an outer case, a burner, a combustion chamber/heat exchanger, a standing pilot ignition system, a pilot light sensing control valve, a flue, a draft hood, an air intake, a burner control thermostat, and an outer case. Basic residential gas floor and basic gas room heaters rely on gravity for air circulation. Basic residential wall gravity, floor, and room heaters differ primarily in the enclosure design and how they are installed. Vented gas hearth DHE, sold as fireplaces, fireplace inserts, or gas stoves, can be used to provide residential space heating, while also simulating wood-burning products. A basic vented hearth product consists of a simple heat exchanger, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue/vent, an air intake, a burner control thermostat, ceramic logs, an outer case, and a glass viewing pane.

Residential pool heaters raise the water temperature in pools, allowing use of the pool when ambient temperatures are low. A basic residential gas pool heater is comprised of an outer case, a combustion chamber with refractory, a standing pilot ignition system, a pilot light sensing control valve, a burner, a heat exchanger, an air intake, a flue/vent, a cold water inlet and hot water outlet, pressure and water safety switches, and a burner control thermostat with user interface.

3.1.2 Definitions

The National Appliance Energy Conservation Act (NAECA) established the definition of a “residential water heater” (42 United States Code (U.S.C.) 6291(27)) as follows:

Residential water heater means a product that uses oil, gas, or electricity to heat potable water for use outside the heater upon demand, including –

1. Storage-type units which heat and store water at a thermostatically controlled temperature, including gas storage water heaters with an input of 75,000 British thermal units [Btu] per hour [h] or less, oil storage water heaters with an input of 105,000 Btu per hour or less, and electric storage water heaters with an input of 12 kilowatts [kW] or less;
2. Instantaneous-type units which heat water, but contain no more than one gallon of water per 4,000 Btu per hour of input, including gas instantaneous water heaters with an input of 200,000 Btu per hour or less, oil instantaneous water heaters with an input of 210,000 Btu per hour or less, and instantaneous electric water heaters with an input of 12 kilowatts or less; and,
3. Heat pump-type units, with a maximum current rating of 24 amperes at a voltage no greater than 250 volts, which are products designed to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water, including all ancillary equipment such as fans, storage tanks, pumps, or controls necessary for the device to perform its function. Section 430.2 of 10 Code of Federal Regulations (CFR).

The definition of a residential water heater is further described in appendix E to subpart B of part 430 of 10 CFR as follows:

1. Gas-Fired Storage-Type Water Heater means a water heater that uses gas as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180 °F [degrees Fahrenheit] (82 °C [degrees Celsius]), has a nominal input of 75,000 Btu (79 MJ [megajoules]) per hour or less, and has rated storage capacity of not less than 20 gallons (76 liters) nor more than 100 gallons (380 liters);
2. Oil-Fired Storage-Type Water Heater means a water heater that uses oil as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180 °F (82 °C), has a nominal input of 105,000 Btu/h (110 MJ/h) or less, and has a manufacturer's rated storage capacity of 50 gallons (90 liters) or less;
3. Electric Storage-Type Water Heater means a water heater that uses electricity as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180 °F (82 °C), has a nominal input of 12 kilowatts (40,956 Btu/h) or less, and has a rated storage capacity of not less than 20 gallons (76 liters) nor more than 120 gallons (450 liters);
4. Tabletop Water Heater means a water heater in a rectangular box enclosure designed to slide into a kitchen countertop space with typical dimensions of 36 inches high, 25 inches deep and 24 inches wide;
5. Instantaneous Gas-fired water heater means a water heater that uses gas as the energy source, initiates heating based on sensing water flow, is designed to deliver water at a controlled temperature of less than 180 °F (82 °C), has an input greater than 50,000 Btu/h (53 MJ/h) but less than 200,000 Btu/h (210 MJ/h), and has a manufacturer's specified storage capacity of less than 2 gallons (7.6 liters); and,
6. Instantaneous Electric Water Heater–Reserved

The energy conservation standards for residential water heaters are represented in terms of the energy factor (EF) in appendix E of subpart B, section 430 of 10 CFR. (42 U.S.C. 6295(e)(1)) The EF is the ratio of the heat delivered to the energy consumed according to the specific test procedure for residential water heaters. The EF accounts for both recovery efficiency and standby losses at prescribed patterns of hot-water draws totaling 64.3 gallons per day.

In DOE's existing regulations, four types of residential heating equipment are referred to as direct heating equipment. DOE refers to these four types of heating equipment (*i.e.*, wall fan DHE, wall gravity DHE, floor DHE, and room DHE) as "traditional" DHE in the final rule associated with this TSD. In the final rule, DOE defines a fifth type of direct heating equipment—vented hearth DHE. DOE defines vented home heating equipment as "home heating equipment, not including furnaces, designed to furnish warmed air to the living space of a residence, directly from the device, without duct connections (except that boots not to exceed 10 inches beyond the casing may be permitted) and includes: vented wall furnace, vented floor furnace, and vented room heater." Section 430.2 of 10 CFR.

Section 430.2 defines a vented wall furnace (gravity type and fan type), vented floor furnace, and vented room heater:

1. Vented wall furnace means a self-contained vented heater complete with grilles or the equivalent, designed for incorporation in, or permanent attachment to, a wall of a residence and furnishing heated air circulated by gravity or by a fan directly into the space to be heated through openings in the casing.
2. Vented floor furnace means a self-contained vented heater suspended from the floor of the space being heated, taking air from combustion from outside this space. The vented floor furnace supplies heated air circulated by gravity or by a fan directly into the space to be heated through openings in the casing.
3. Vented room heater means a self-contained, free standing, nonrecessed, vented heater for furnishing warmed air to the space in which it is installed. The vented room heater supplies heated air circulated by gravity or by a fan directly into the space to be heated through openings in the casing.

Before the enactment of NAECA, EPCA included home heating equipment in DOE's appliance standards program. DOE construed this term as covering unvented as well as vented products, and prescribed a separate test procedure for each. 43 FR 20128, 20132 (May 2, 1978). However, when NAECA replaced the term "home heating equipment" with "direct heating equipment" in NAECA's amendments to EPCA in 1987 (42 U.S.C. 6295(e)(3)), the new energy conservation standards for this equipment affected only gas products. The statutorily prescribed standards used the AFUE descriptor, which applies only to vented equipment. The AFUE represents the heat transferred to the conditioned space divided by the fuel energy supplied. Because of the limitation imposed by the statute's use of the AFUE descriptor, subsequent DOE actions concerning direct heating equipment have focused solely on vented products.

DOE defines a pool heater under NAECA as "an appliance designed for heating nonpotable water contained at atmospheric pressure, including heating water in swimming pools, spas, hot tubs and similar applications." (42 U.S.C. 6291(25))

The energy conservation standard for pool heaters is represented by the thermal efficiency. Section 430.32(k) of 10 CFR. (42 U.S.C. 6295(e)(2)) Thermal efficiency represents the heat transferred to the nonpotable water divided by the fuel energy supplied.

3.1.3 Product Classes

DOE categorized the product types (*i.e.*, residential water heaters, residential direct heating equipment, and pool heaters) into product classes and formulated a separate energy conservation standard for each class. The criteria for separation into different classes are type of energy used, capacity, and other performance-related features such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295(q) and 6316(a)) For residential water heaters, the product classes are based on energy source (*i.e.*, gas or electric) and design (*i.e.*, storage-type, tabletop, and instantaneous or "tankless"). The product classes shown in Table 3.1.1 were established by the January 17, 2001, Energy Conservation Standards for Water Heaters Final Rule (the January 2001 final rule) amending the energy conservation standards for residential water heaters and incorporated into section 430.32(d). 66 FR 4474, 4497 (January 17, 2001).

Table 3.1.1 Product Classes for Residential Water Heaters

Residential Water Heater Type	Characteristics
Gas-Fired Storage Type	Nominal input of 75,000 Btu/h or less; rated storage volume from 20 to 100 gallons
Oil-Fired Storage Type	Nominal input of 105,000 Btu/h or less; rated storage volume of 50 gallons or less
Electric Storage Type	Nominal input of 12 kW (40,956 Btu/h) or less; rated storage volume from 20 to 120 gallons
Tabletop	Dimensions of 36 inches high, 25 inches deep, and 24 inches wide
Instantaneous Gas-Fired	Nominal input of over 50,000 Btu/h up to 200,000 Btu/h; rated storage volume of 2 gallons or less
Instantaneous Electric	Input of 12 kW or less; contains no more than one gallon of water per 4,000 Btu/h of input

Table 3.1.2 shows the product classes for direct heating equipment established by NAECA. (42 U.S.C. 6295(e)(3)) However in the final rule, DOE has reduced the number of heating capacity ranges for direct heating equipment to better reflect the distribution of direct heating equipment available on the market. In addition, DOE has created a separate product class of direct heating equipment for gas hearth DHE (Table 3.1.2).

Table 3.1.2 Product Classes for Direct Heating Equipment

Direct Heating Equipment Type	Heating Capacity (Btu/h)
Gas Wall Fan	Up to 42,000
	Over 42,000
Gas Wall Gravity	Up to 27,000
	Over 27,000 up to 46,000
	Over 46,000
Gas Floor	Up to 37,000
	Over 37,000
Gas Room	Up to 20,000
	Over 20,000 up to 27,000
	Over 27,000 up to 46,000
	Over 46,000
Gas Hearth	Up to 20,000
	Over 20,000 up to 27,000
	Over 27,000 up to 46,000
	Over 46,000

Gas hearth direct heating equipment class description. Vented hearth products include gas-fired products such as fireplaces, fireplace inserts, stoves, and log sets that typically include aesthetic features and that provide space heating. DOE has concluded that such products meet its definition of "vented home heating equipment," because they are designed to furnish warmed air to the living space of a residence. DOE has also concluded, therefore, that they are covered products under EPCA and are properly classified as DHE.

DOE found there were two types of vented hearth products currently produced by manufacturers. The primary difference between the two types of hearth products is that decorative units are intended only to provide the ambiance and aesthetic utility associated with a solid fuel (e.g., wood-burning) fireplace with little or no heat output to the living space, while heating hearth products are intended to provide heat to the living space along with the aesthetic utility. Heating-type products are often shipped with additional accessories that decorative products do not have, such as thermostats to control the heat output and blowers that distribute hot air to the room. DOE research suggests that this additional equipment is typically optional and hence not very useful to distinguish between heaters and decorative units.

DOE is including a maximum input capacity limit into its definition of vented hearth heater to provide a clear distinguishable way for DOE, manufacturers, and consumers to identify which products provide "warmed air to the residence," as compared with those designed purely for aesthetic purposes. Because of the nature of hearth products (i.e., the presence of a flame), all hearth products create heat and nearly all of the hearth products provide some amount of that heat, however small that may be, to the surrounding living space.

Vented hearth heater means a vented appliance which simulates a solid fuel fireplace and is designed to furnish warm air, with or without duct connections, to the space in which it is installed. The circulation of heated room air may be by gravity or mechanical means. A vented hearth heater may be freestanding, recessed, zero clearance, or a gas fireplace insert or stove. Those heaters with a maximum input capacity less than or equal to 9,000 British thermal units per hour (Btu/h), as measured using DOE's test procedure for vented home heating equipment (10 CFR part 430, subpart B, appendix O), are considered purely decorative and are excluded from DOE's regulations.

For pool heaters, the only product class is gas-fired pool heaters, which is established by NAECA. (42 U.S.C. 6295(e)(2))

3.1.4 Product Test Procedures

Test procedures already exist for all three products covered by this rulemaking. DOE established test procedures for residential water heaters, residential direct heating equipment, and pool heaters through the rulemaking process, initially established by a final rule published on October 17, 1990, and codified in appendix E to subpart B of 10 CFR part 430. 55 FR 42163. DOE amended the residential water heater test procedure on May 11, 1998, by adding the following provisions: (1) a revision to the method used in determining the first hour rating of storage-type water heaters, (2) an additional rating for electric and instantaneous gas-fired water heaters, and (3) a revision to the definition of a heat pump water heater. 63 FR 25996. On July 20, 1998, DOE published in the *Federal Register* a correction to the May 1998 final rule, which added residential water heater testing schematics. 63 FR 38737. Along with the amended energy conservation standards published in the January 2001 final rule, DOE also amended the test procedure by adding a definition for tabletop water heaters and reaffirming the test methods specified in appendix E to subpart B of 10 CFR Part 430. 66 FR 4476.

DOE prescribed a test procedure for vented types of gas-fired direct heating equipment in a notice published in the *Federal Register* on May 2, 1978. 43 FR 20182. On May 12, 1997, DOE published a final test procedure rule that amended the test procedures for direct heating equipment, and, in particular, vented home heating equipment. 62 FR 26140. The May 1997 final rule included modified calculation procedures for the weighted-average steady-state efficiency and AFUE for certain manually controlled heaters, and added a procedure for calculating the annual energy consumption of fossil fuel and auxiliary electrical energy for these types of products.

On May 12, 1997, DOE also published in the *Federal Register* a final rule that amended the test procedure for pool heaters. 62 FR 26140. The May 1997 final rule updated the referenced American National Standards Institute (ANSI) standard for pool heaters from ANSI Standard Z21.56-1986, Gas-Fired Pool Heaters, to ANSI Standard Z21.56-1994, Gas-Fired Pool Heaters. This update added a procedure for calculating the annual energy consumption of fossil fuel auxiliary electrical energy for pool heaters and a seasonal efficiency descriptor. 62 FR 26141.

3.2 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade associations; domestic and international manufacturers of residential water heaters, direct heating equipment and pool heaters, and their corresponding market shares; and regulatory and non-regulatory programs. The market assessment also provides historical shipment data; describes the cost structure for the residential water heater, direct heating equipment, and pool heater industries; and summarizes relevant market performance data for each product type.

3.2.1 Trade Associations

DOE recognizes the importance of trade groups in disseminating information and providing growth to the industry they support. To gain insight into the residential water heater, direct heating equipment, and pool heater industries, DOE researched various associations available to manufacturers, suppliers, and users of such equipment. DOE also used the member lists of these groups to construct a database of domestic manufacturers.

DOE identified several trade groups that support or have an interest in the residential water heater, direct heating equipment, and pool heater industries, including AHRI, the Hearth, Patio & Barbecue Association (HPBA), and the Association of Pool and Spa Professionals (APSP).

3.2.1.1 Air-Conditioning, Heating, and Refrigeration Institute

AHRI[a] is a national trade association representing manufacturers of air conditioning, heating, ventilation and commercial refrigeration equipment and components. AHRI was established in January of 2008, when the Air-Conditioning and Refrigeration Institute (ARI) merged with the Gas Appliance Manufacturers Association (GAMA). AHRI's scope includes gas-fired, oil-fired, and electric products and equipment. AHRI has over 300 member companies that account for more than 90 percent of the residential and commercial air conditioning, space heating, water heating, and commercial refrigeration equipment manufactured and sold in North America.[2] AHRI serves many functions, including advocating for the heating, ventilation, air-conditioning and refrigeration (HVACR) industry; certifying product performance; compiling statistical reports of industry data; sponsoring HVACR research programs; and supporting HVACR technician education programs.[3] AHRI maintains the AHRI Efficiency Certification Program. AHRI also maintains a database of products and equipment tested under its certification program on its website. The majority of heating products currently manufactured by member and non-member manufacturers are included in this database. Table 3.2.1 shows manufacturers of products covered by this rulemaking represented in AHRI's Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment (hereafter the AHRI directory).

[a] For more information, please visit www.ahrinet.org.

Table 3.2.1 Manufacturers Whose Products Are Included in the AHRI Directory[b]

Residential Water Heaters	Direct Heating Equipment	Pool Heaters
A.O. Smith Corporation	Empire Comfort Systems, Inc.	Hayward Industries, Inc.
Bock Water Heaters, Inc.	Monitor Products	Zodiac Pool Systems, Inc.
Bradford White Corporation	Louisville Tin and Stove Co.	Lochinvar Corporation
Bosch Water Heating	Rinnai Corporation	Pentair, Inc.
EEMax, Inc.	Williams Furnace Company	Raypak
General Electric		
Heat Transfer Products, Inc.		
Lochinvar Corporation		
Rheem-Ruud		
Rinnai Corporation		
Takagi Industrial Co. USA		
Vaughn Manufacturing Corporation		

The majority of residential water heater, direct heating equipment, and pool heater manufacturers identified in section 3.2.2.1 are represented by AHRI.

3.2.1.2 Hearth, Patio & Barbecue Association

HPBA "includes manufacturers, retailers, distributors, manufacturers' representatives, service and installation firms, and other companies and individuals - all having business interests in and related to the hearth, patio, and barbecue products industries."[4c]

3.2.1.3 Association of Pool and Spa Professionals

APSP is "the world's largest international trade association for the swimming pool, spa, and hot tub industry. APSP works with regulatory and legislative bodies to ensure that their codes, ordinances, and legislation are written to the safest and most current standards. The association's mission is to ensure consumer safety and enhance the business success of its members."[5] APSP also delivers public relations, advertising, and water safety messages to consumers, and maintains industry data and statistics on the pool and spa industries. Members can obtain information on the products available to consumers, historical and geographical pool and spa installation statistics, and other types

---

[b] A.O Smith Water Corporation refers to A. O. Smith Water Products Company, State Water Heaters, Reliance Water Heater Company, Apollo Comfort Products, Maytag, US Craftmaster, American Water Heater Company, and GSW Water Heating. Bosch Water Heating is a division of Bosch USA, which is a branch of Bosch Group. Rheem-Ruud refers to Rheem Manufacturing Company, Ruud Water Heating, Paloma, Marathon and Richmond Water Heaters. Rinnai Corporation is a subsidiaries of Rinnai Japan. Takagi Industrial Company USA is a division of Takagi. Williams Furnace Company is a subsidiary of Continental Materials Corporation. Pentair refers to Pentair Water Pool and Spa, Incorporated. Raypak refers to Raypak, Incorporated.

[c] For more information, visit www.hpba.org/index.php?id=46.

of data. Additionally, the APSP offers pool and spa professionals resources and tools to assist in business operations.

3.2.2 Manufacturer Information

The following section provides information about manufacturers of residential water heaters, direct heating equipment, and pool heaters, including estimated market shares, potential small business impacts, and product distribution channels.

3.2.2.1 Manufacturers and Market Shares

Using publicly available data (*e.g.*, *Appliance Magazine* and market assessments from third parties), DOE estimated the market shares for manufacturers of each of the three products contained in this standards rulemaking. Manufacturers may offer multiple brand names.

DOE estimates that there are approximately 26 domestic manufacturers of residential water heaters.[6] The large majority of the domestic market is controlled by three U.S. manufacturers: Rheem-Rudd, A.O. Smith Corporation (including State Industries and American Water Heater), and Bradford-White.[7] Five manufacturers hold most of the remaining domestic market share, including: Bock Water Heaters, Inc.; Bosch Water Heating; Noritz America; Rinnai America Corporation; and Takagi Industrial Co. USA. Table 3.2.2 lists these manufacturers.

Table 3.2.2 Major and Other Residential Water Heater Manufacturers

Major Manufacturers*	**Other Manufacturers**
Rheem-Ruud	Bock Water Heaters, Inc.
A. O. Smith Corporation	Bosch Water Heating
Bradford White Corporation	Noritz America
	Rinnai America Corporation
	Takagi Industrial Co. USA

* Manufacturers with 10 percent or more of market share.

Figure 3.2.1 shows the 2008 market shares for domestic residential water heater manufacturers as depicted in the September 2009 issue of *Appliance Magazine*.

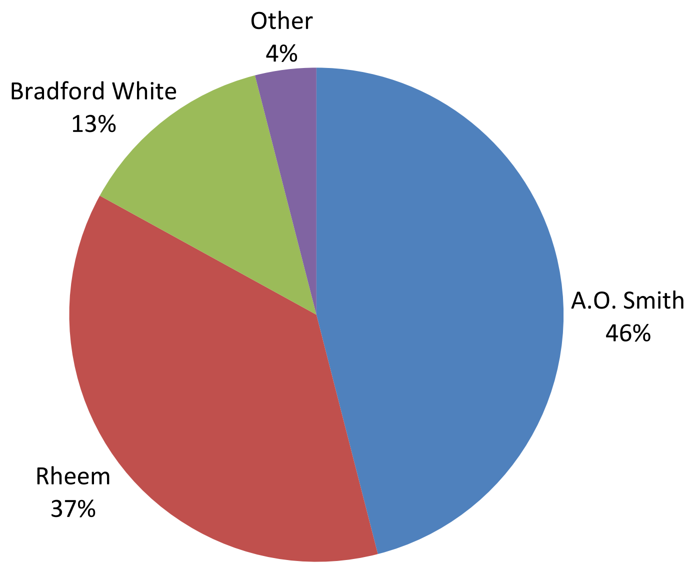


Figure 3.2.1 2008 Market Shares for the Domestic Residential Water Heaters[8]

The residential water heater market can be further divided into manufacturers of gas, oil-fired, and electric storage water heaters, and gas or electric instantaneous water heaters. Table 3.2.3 shows manufacturers that produce these types of residential water heaters.

Table 3.2.3 Residential Water Heater Manufacturers by Technology Type

Manufacturer	Residential Water Heater Type				
	Gas Storage	Oil-Fired Storage	Electric Storage	Instantaneous Gas	Instantaneous Electric
A. O. Smith Corporation	X	X	X	X	
Bock Water Heaters, Inc.	X	X			
Bosch Water Heating				X	X
Bradford White Corporation	X	X	X		
Eccotem Systems, LLC				X	
EEMax, Inc				X	
General Electric			X		
Heat Transfer Products, Inc.		X			
Lochinvar Corporation	X		X		
Noritz				X	
Rheem-Ruud	X		X	X	
Rinnai America Corporation				X	
Takagi Industrial Co. USA				X	
Vaughn Manufacturing			X		
TOTALS	5	4	6	8	1

DOE estimates that there are 6 domestic manufacturers of traditional direct heating equipment and 16 manufacturers of gas hearth DHE.[d] Table 3.2.4 and Table 3.2.5 list these manufacturers.

Table 3.2.4 Gas-Fired Traditional Direct Heating Equipment Manufacturers

Major Manufacturers*	Other Manufacturers
Empire Comfort Systems, Inc.	Monitor Products, Inc.
Louisville Tin and Stove Co.	Rinnai
Williams Furnace Company**	United States Stove Company

*Major manufacturers have at least 10% market share.
** Williams Furnace Company is a subsidiary of Continental Materials Corporation.

[d] Estimate based on membership in AHRI (former GAMA members), membership in HPBA, and online product searches.

Table 3.2.5 Gas Hearth DHE Direct Heating Equipment Manufacturers[e]

Major Manufacturers	Minor Manufacturers
Hearth & Home Technologies, Inc.	Blaze King Industries
Lennox International Inc	Buck Stove Corporation
Monessen Hearth Systems Co	Breckwell Hearth Products
	Empire Comfort Systems Inc
	Golden Blount, Inc
	Hearthstone Quality Home Heating Products, Inc.
	Hussong Mfg. Co., Inc.
	Jøtul North America, Inc.
	Mendota Hearth Products
	Rinnai
	Thelin Co. Inc
	Travis Industries, Inc.
	Wolf Steel Inc. (Napoleon Fireplaces)

Due to the small total size of the traditional direct heating equipment market and confidentiality concerns, DOE was unable to disclose any market share data for traditional direct heating equipment manufacturers or hearth equipment manufacturers. DOE divided manufacturers into "major" and "other" based on the current industry characteristics, DOE research, and discussions with manufacturers. Major companies have larger market shares.

DOE identified five domestic manufacturers of residential gas-fired pool heaters. Table 3.2.6 lists these manufacturers.

Table 3.2.6 Gas-Fired Pool Heater Manufacturers[f]

Major Manufacturers*	Other Manufacturers
Hayward Industries, Inc.	Lochinvar Corporation
Zodiac Pool Systems, Inc.	
Raypak	
Pentair	

*Major manufacturers have at least 10% market share.

Due to the small total size of the pool heater market and confidentiality concerns, DOE was unable to disclose any market share data for residential pool heater manufacturers. DOE divided pool heater manufacturers into "major" and "other" categories based on the current industry characteristics, DOE research, and discussions with manufacturers. Major companies have larger market shares.

3.2.2.2 Small Business Impacts

[e] Lennox Hearth Products refers to Lennox International, Incorporated. Hearth and Home Technologies is a subsidiary of HNI Corporation.
[f] Raypak refers to Raypak, Incorporated. Pentair refers to Pentair Water Pool and Spa, Incorporated.

DOE realizes that small businesses may be disproportionately affected by the promulgation of energy conservation standards for residential water heaters, direct heating equipment, and pool heaters. The Small Business Administration (SBA) defines small business manufacturing enterprises for residential water heaters, direct heating equipment, and pool heaters as those having 500 employees or fewer.[9] SBA lists small business size standards for industries as they are described in the North American Industry Classification System (NAICS). The size standard for an industry establishes the largest size that a for-profit entity can be while still qualifying as a small business for Federal Government programs. These size standards are generally expressed in terms of the average annual receipts or the average employment of a firm. Residential water heater manufacturing is classified under NAICS 335228, "Other Major Household Appliance Manufacturing," and direct heating equipment and pool heater manufacturing is classified under NAICS 333414, "Heating Equipment (except warm air furnaces) Manufacturing." The size standard is 500 employees or fewer for both NAICS codes.

DOE studied the potential impacts on these small businesses as a part of the manufacturer impact analysis (chapter 12). Table 3.2.7 lists the small business residential water heaters, direct heating equipment, and pool heating manufacturers that DOE identified.

Table 3.2.7 Small Business Manufacturers of Residential Water Heaters, Direct Heating Equipment, and Pool Heaters

Water Heaters	Direct Heating Equipment	Pool Heaters
Bock Water Heaters	Empire Comfort Systems, Inc.	Lochinvar Corporation
Eccotemp Systems, LLC	Louisville Tin and Stove Co.	
EEMax, Inc.	Blaze King Industries	
Heat Transfer Products, Inc.	Breckwell Hearth Products	
Therma-Flow, Inc.	Buck Stove Corporation	
Vaughn Manufacturing Corporation	Golden Blount, Inc	
	Hearthstone Quality Home Heating Products, Inc.	
	Hussong Mfg. Co, Inc. (Kozy Heat)	
	Mendota Hearth Products	
	Thelin Co. Inc	
	Travis Industries, Inc	
	United States Stove Company	

3.2.3 Distribution Channels

Analysis of the distribution channels of products covered by this rulemaking is an important facet of the market assessment. DOE gathered information from publicly available sources regarding the distribution channels for residential water heaters, direct heating equipment, and pool heaters.

The residential water heater market can be divided into two areas: replacement of existing units and new construction. Between 49 and 59 percent of residential water heaters are distributed through wholesalers.[10] These wholesalers then resell residential water heaters to contractors and plumbers, plumbing supply houses, local hardware stores, and other retail channels. For gas instantaneous water heaters in particular, the wholesale distribution channel accounts for an even larger percentage. Residential water heaters are also sold through retail distribution (between 41 and 51 percent).[11] These residential water heaters are sold directly by residential water heater manufacturers to home improvements stores, chain hardware stores, and other large retailers. According to DOE's 2000 water heater technical support document (TSD), approximately 60 percent of replacements were sold through the retail distribution channel.[12] Alternatively, customers may purchase a residential water heater and install it themselves or hire a contractor to complete the installation. Homebuilders, contractors, and plumbers purchase residential water heaters for new construction.

Appliance Magazine's 56th annual statistical review stated that 8.19 million residential water heaters were shipped in 2008.[13] According to the Northwest Energy Efficiency Alliance (NEEA)'s analysis of residential water heater distribution channels, 20 percent were purchased by homebuilders for use in new construction. The remaining 80 percent of sales were retrofit units replacing existing residential water heaters. Of these retrofit units, approximately 52 percent were purchased and installed by consumers, and approximately 48 percent were installed by contractors and plumbers.[14]

For analysis purposes, DOE defined four distribution channels for residential water heaters: Replacement A, Replacement B, New Homes A, and New Homes B. (Figure 3.2.2).

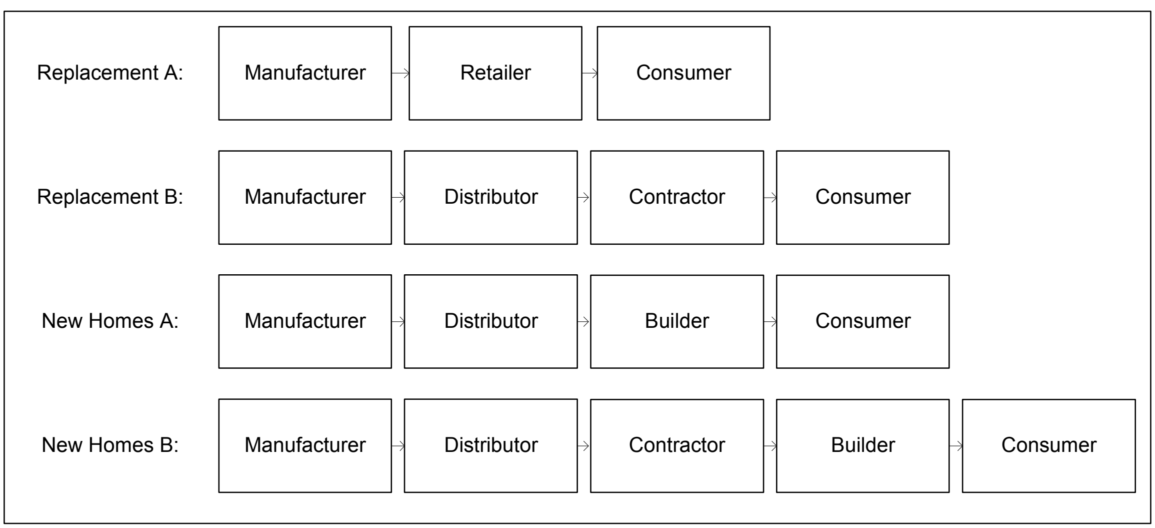


Figure 3.2.2 Water Heaters Distribution Channel

Consumer purchases and installations typically do not play a role in the established distribution channels of direct heating equipment. For replacement applications, most sales go through distributors to contractors, and then to consumers. In new home applications, most sales go through distributors to contractors hired by the builder. Thus, DOE defined two distribution channels for analysis purposes: Replacement and New Homes (Figure 3.2.3).

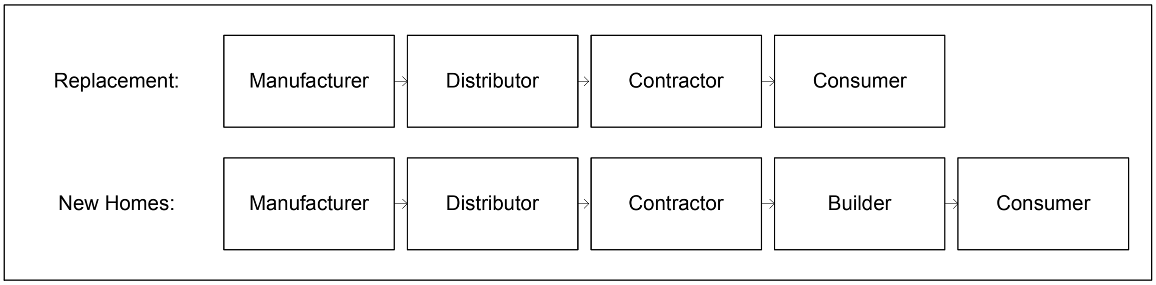


Figure 3.2.3 Direct Heating Equipment Distribution Channel

For pool heaters in replacement applications, most sales go through distributors or retailers to pool service companies. In most new home applications, the pool builder purchases the equipment from a distributor or wholesaler. Thus, DOE defined two distribution channels for analysis purposes: Replacement and New Homes (Figure 3.2.4).

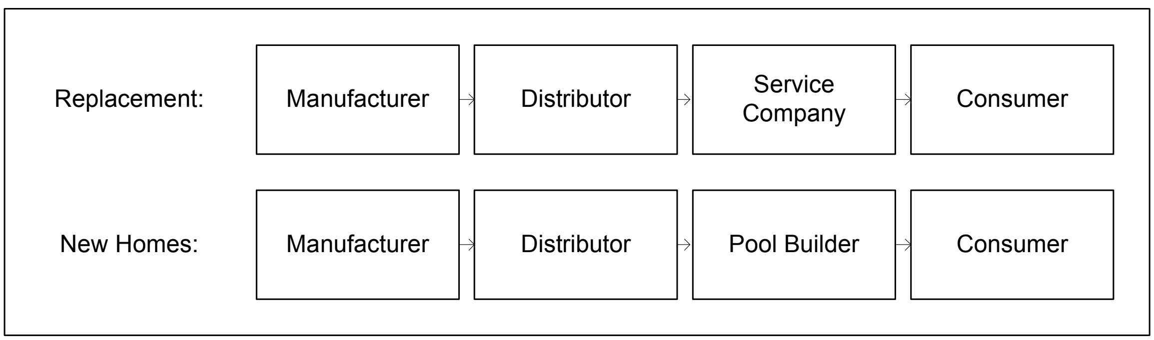


Figure 3.2.4 Pool Heater Distribution Channel

DOE further describes the distribution channels, as well as the markups for each component of the distribution channel, in chapter 6 of the final rule TSD (Markups to Determine Product Price).

3.2.4 Regulatory Programs

The following section details current regulatory programs mandating energy conservation standards for residential water heaters, direct heating equipment, and pool heaters. Section 3.2.4.1 discusses current Federal energy conservation standards, and section 3.2.4.2 provides an overview of existing State standards. Sections 3.2.4.3 and 3.2.4.4 review standards in Canada and Mexico that may affect companies servicing the domestic market.

3.2.4.1 Current Federal Energy Conservation Standards

NAECA established energy conservation standards for residential water heaters, direct heating equipment,[g] and pool heaters, and required that DOE conduct two cycles of rulemakings to determine if more stringent standards are economically justified and technologically feasible for these products. (42 U.S.C. 6295 (e)(1) and (4)) On February 7, 1989 and October 17, 1990, DOE issued a final rule codifying the standards prescribed by NAECA, and thereby established the first set of energy conservation standards for residential water heaters, direct water heating equipment, and pool heaters. 54 FR 6077 (February 7, 1989) and 55 FR 42163 (October 17, 1990).

Pursuant to 42 U.S.C. 6295(e)(4)(A), on January 17, 2001, DOE published in the *Federal Register* the January 2001 final rule, effective January 20, 2004, amending the energy conservation standards for residential water heaters. 66 FR 4474.

Table 3.2.8 Federal Energy Conservation Standards for Residential Water Heaters

Residential Water Heater Class	Minimum Energy Factor (EF)
Gas-Fired Storage Type	0.67 – (0.0019 x Rated Storage Volume in gallons)
Oil-Fired Storage Type	0.59 – (0.0019 x Rated Storage Volume in gallons)
Electric Storage Type	0.97 – (0.00132 x Rated Storage Volume in gallons)
Instantaneous Gas-Fired Type	0.62 – (0.0019 x Rated Storage Volume in gallons)
Instantaneous Electric Type	0.93 – (0.00132 x Rated Storage Volume in gallons)
Tabletop	0.93 – (0.00132 x Rated Storage Volume in gallons)

DOE initially analyzed energy conservation standards for direct heating equipment as part of an eight-product standards rulemaking. When DOE analyzed direct heating equipment in these earlier proceedings, it considered only products categorized as vented home heating equipment. DOE issued a notice of proposed rulemaking (NOPR) on March 4, 1994, proposing to amend the energy conservation standards for direct heating equipment and other consumer products. 59 FR 10464. The Department of Interior and Related Agencies Appropriations Act for Fiscal Year 1996 (P.L. 104-134) imposed a moratorium on proposing or issuing final rules for appliance standards rulemakings for the remainder of Fiscal Year 1996, thereby preventing DOE from finalizing the 1994 proposed standards and leaving the existing NAECA efficiency levels in place. Table 3.2.9 presents these energy conservation standards for direct heating equipment.

[g] Initially, EPCA included vented and unvented home heating equipment in DOE's appliance standards program. However, EPCA did not specifically use the term direct heating equipment. NAECA prescribed energy conservation standards for direct heating equipment instead of vented and unvented home heating equipment, but NAECA did not include a definition of the products covered under the direct heating equipment category. Since DOE has established test procedures to measure the energy efficiency of vented home heating equipment and the test procedures for unvented home heating equipment do not have an energy efficiency measure, DOE has determined that direct heating equipment only refers to vented home heating equipment for the purpose of this rulemaking.

Table 3.2.9 Federal Energy Conservation Standards for Direct Heating Equipment*

Direct Heating Equipment Design Type	Product Class, by Input Rating (Btu/h)	AFUE %
Gas Wall Fan	Up to 42,000	73
	Over 42,000**	74
Gas Wall Gravity	Up to 10,000	59
	Over 10,000 up to 12,000	60
	Over 12,000 up to 15,000	61
	Over 15,000 up to 19,000	62
	Over 19,000 up to 27,000	63
	Over 27,000 up to 46,000**	64
	Over 46,000	65
Gas Floor	Up to 37,000	56
	Over 37,000**	57
Gas Room	Up to 18,000	57
	Over 18,000 up to 20,000	58
	Over 20,000, up to 27,000	63
	Over 27,000 up to 46,000**	64
	Over 46,000	65

*Includes all of the product classes set forth in the Energy Policy and Conservation Act (EPCA) and codified at 10 CFR Part 430.32(i).
**Representative product classes that DOE intends to analyze.

As with direct heating equipment, DOE initially analyzed standards for pool heaters as part of the eight-product standards rulemaking of 1994, 59 FR 10464, but never finalized the proposed standards (for reasons explained above). DOE has not amended the energy conservation standards for pool heaters since NAECA established them in 1987. 42 U.S.C 6295 (e)(2) Existing energy conservation standards for residential pool heaters specify a thermal efficiency for pool heaters of no less than 78 percent. 10 CFR part 430.32(k).

3.2.4.2 State Energy Conservation Standards

The following States have established appliance energy efficiency regulations: Arizona, California, Connecticut, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington. Of these, California is the only State that explicitly regulates equipment covered in this rulemaking.[15]

The State of California mandates energy conservation standards for residential water heaters. State standard levels are identical to Federal standard levels for each covered product. California regulations extend the scope of Federal standards, including standards for products outside of the rated storage capacity range and input capacity range stated for the product types covered by Federal standards. Additionally, California has specific regulations for instantaneous oil-fired water heaters, which are similar to the Federal standards for oil-fired storage water heaters.[16] Table 3.2.10 presents California's water heater standards.

Table 3.2.10 California State Efficiency Standards for Residential Water Heaters[17]

Appliance	Energy Source	Input Rating	Rated Storage Volume *gallons*	Minimum Energy Factor
Storage Water Heaters	Gas	≤ 75,000 Btu/h	< 20	0.62 – (0.0019 x Volume)
Storage Water Heaters	Gas	≤ 75,000 Btu/h	> 100	0.62 – (0.0019 x Volume)
Storage Water Heaters	Oil	≤ 105,000 Btu/h	> 50	0.59 – (0.0019 x Volume)
Storage Water Heaters	Electricity	≤ 12 kW	> 120	0.93 – (0.00132 x Volume)
Instantaneous Water Heaters	Gas	≤ 50,000 Btu/h	Any	0.62 – (0.0019 x Volume)
Instantaneous Water Heaters	Gas	≤ 200,000 Btu/h	≥ 2	0.62 – (0.0019 x Volume)
Instantaneous Water Heaters	Oil	≤ 210,000 Btu/h	Any	0.59 – (0.00132 x Volume)
Instantaneous Water Heaters	Electricity	≤ 12 kW	Any	0.93 – (0.00132 x Volume)

The State of California also mandates energy conservation standards for direct heating equipment. These standard levels are identical to Federal energy conservation standard levels.[18]

California mandates energy conservation standards for pool heaters as well. The State's gas-fired pool heater standard is identical to the Federal standard level with an additional requirement that prohibits the use of constant burning pilots.[19] California also issues standards for oil-fired and electric heat pump pool heaters. Table 3.2.11 provides these pool heater standards.[20]

Table 3.2.11 California State Energy Conservation Standards for Pool Heaters[21]

Residential Pool Heater Type	Standard Level
Oil Fired	Thermal Efficiency: 78%
Heat Pump	Average Coefficient of Performance: 3.5

3.2.4.3 Canadian Standards Association

The Canadian Standards Association (CSA) is an independent standards-setting agency that establishes test procedures and efficiency standards that are typically adopted by the Canadian Government.

Residential Water Heaters. CSA has specified energy conservation standards for residential water heaters. The CSA standards divide residential water heaters into several categories and subcategories, summarized in Table 3.2.12.

Table 3.2.12 Canadian Efficiency Standards for Residential Water Heaters[22]

Water Heater Type	Product Class	Efficiency Standard Description
Gas-Fired Storage	Input rating ≤ 21.98 kW (75,000 Btu/h) and storage capacity 76 to 380 liters	Minimum EF: 0.67 – 0.0005V
Oil-Fired Storage	Input rating ≤ 30.5 kW (107,000 kJ/h) and storage capacity ≤ 190 liters	Minimum EF: 0.59 – 0.0005V
Electric Storage	**Bottom Inlet**	
	50 to 270 liters	Maximum Standby Loss: 40 + (0.20V)
	> 270 to 454 liters	Maximum Standby Loss: (0.472V) – 33.5
	Top Inlet	
	50 to 270 liters	Maximum Standby Loss: 35 + (0.20V)
	> 270 to 454 liters	Maximum Standby Loss: (0.472V) – 38.5

Note: V=rated storage capacity in liters; EF=energy factor as defined by CSA P.3-04 for gas-fired water heaters and CAN/CSA-B211-00 for oil-fired water heaters.

Direct Heating Equipment. Canada has product classes for vented gas fireplaces and fireplace heaters. Vented gas fireplaces are primarily used for aesthetic purposes, whereas vented gas fireplace heaters are designed to provide heat to the space where they are installed. Canada has not issued energy conservation standards for either of these products classes and did not appear to have plans to issue standards as of April 2009.[23]

Pool Heaters. CSA has specified an energy conservation standard for gas pool heaters similar to Federal energy conservation standards. This standard sets a minimum thermal efficiency of 78 percent.

3.2.4.4 Mexico

Mexico has specified energy conservation standards for gas water heaters. The Mexican standards divide gas water heaters into domestic and commercial categories, summarized in Table 3.2.12.

Table 3.2.13 Mexican Efficiency Standards for Water Heaters[24]

Water Heater Type	Product Class	Efficiency Standard Description
Gas Fired	Domestic Hot Water Heaters	Minimum Thermal Efficiency: 72%
	Commercial Hot Water Heaters	Minimum Thermal Efficiency: 77%

3.2.5 Voluntary Programs

DOE reviewed several voluntary programs promoting energy efficient residential water heaters, direct heating equipment, and pool heaters in the United States, including the American Council for an Energy Efficiency Economy (ACEEE), the Consortium for

Energy Efficiency (CEE), the Environmental Protection Agency (EPA) ENERGY STAR program, the Federal Energy Management Program's (FEMP) procurement program for energy-efficient products, various rebate programs offered by local utilities, and the Super Efficient Gas Water Heating Appliance Initiative (SEGWHAI).

3.2.5.1 American Council for an Energy Efficient Economy

ACEEE [h] is "dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection." ACEEE conducts technical and policy assessments, advises policy makers and program managers, works collaboratively with businesses and public interest groups, organizes conferences, publishes books, conference proceedings, and reports, and educates consumers and businesses.[25]

ACEEE works with industry to maintain a database of high-efficiency residential water heaters and offers guidance to consumers on how to improve the efficiency of their residential water heaters.

3.2.5.2 Consortium for Energy Efficiency

CEE[i], "a nonprofit public benefits corporation, develops initiatives for its North American members to promote the manufacture and purchase of energy-efficient products and services. The goal of the organization is to induce lasting structural and behavioral changes in the marketplace, resulting in the increased adoption of energy-efficient technologies."[26]

CEE organizes a summary of utility-sponsored rebate and incentive programs for efficient residential water heaters. This summary is available online to encourage consumers to purchase efficient residential water heaters and take advantage of utility rebates.

3.2.5.3 ENERGY STAR

ENERGY STAR,[j] a voluntary labeling program backed by the U.S. Environmental Protection Agency (EPA) and DOE, identifies energy efficient products through a qualification process. To qualify, a product must exceed Federal energy efficiency standards by a specified amount, or if no Federal standard exists, exhibit selected energy-saving features. The ENERGY STAR program qualifies the top quartile of products on the market, meaning that approximately 25 percent of products on the market meet or exceed the ENERGY STAR levels. On April 1, 2008, ENERGY STAR set requirements for gas storage water heaters, whole-home gas tankless water heaters, gas condensing water heaters, heat pump water heaters, and solar water heaters.

[h] For more information, please visit www.aceee.org.
[i] For more information, please visit www.cee1.org.
[j] For more information, please visit www.energystar.gov.

ENERGY STAR released the criteria on April 1, 2008. They took effect on January 1, 2009. Table 3.2.14 summarizes the requirements.

Table 3.2.14 ENERGY STAR Residential Water Heater Criteria Issued on April 1, 2008[27]

Product Type	Criteria
Gas Storage Water Heater	• Minimum EF of 0.62 (0.67 beginning September 1, 2010) • Minimum first hour rating of 67 gallons • Minimum 6-year warranty on sealed system
Whole-Home Gas Tankless Water Heater	• Minimum EF of 0.82 • Minimum gallons per minute of 2.5 over a 77 ºF rise • Minimum 10-year warranty on heat exchanger and 5 years on parts
Gas Condensing Storage Water Heater	• Minimum EF of 0.80 • Minimum first hour rating of 67 gallons • Minimum 8-year warranty on sealed system
Heat Pump Water Heater	• Minimum EF of 2.0 • Minimum first hour rating of 50 gallons per hour • Minimum 6-year warranty on sealed system
Solar Water Heater	• Minimum Solar Fraction of 0.5 • OG-300 certification from the SRCC (Solar Rating and Certification Corporation) • Minimum 10-year warranty on solar collector, 6 years on storage tank, 2 years on controls, and 1 year for piping and parts

3.2.5.4 Federal Energy Management Program

"DOE's FEMP [k] works to reduce the cost and environmental impact of the Federal Government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites."[28] FEMP helps Federal buyers identify and purchase energy-efficient equipment.

FEMP designates standards for water heaters purchased by the Federal Government. The designated FEMP gas water heater standards levels appear in Table 3.2.15, and the FEMP electric water heater standards appear in Table 3.2.16.

[k] For more information, please visit www.eere.energy.gov/femp.

Table 3.2.15 FEMP Gas Water Heater Performance Requirements[29]

Storage Tank Volume	Energy Factor
50 gallons or less	0.62 or higher

Table 3.2.16 FEMP Electric Water Heater Performance Requirements[30]

Storage Tank Volume	Energy Factor
Less than 60 gallons	0.93 or higher
60 gallons or more	0.91 or higher

3.2.5.5 Rebate Programs

Several utilities offer rebate programs for high-efficiency residential water heaters. A small sample of these programs is listed in Table 3.2.17.

Table 3.2.17 Sample Rebate Programs

State	Utility	Product	Requirement	Value $
California	Pacific Gas and Electric Company (PG&E)[31]	Water Heaters	Gas Storage: EF ≥ 0.62 and capacity ≥ 30 gallons Electric Storage: EF ≥ 0.93 and capacity ≥ 40 gallons	$30
Florida	Central Florida Gas[32]	Gas Water Heaters	Storage and tankless installation or replacement	$350-$525
Illinois	City Water Light and Power[33]	Water Heaters	New electric installation or gas replacement and capacity ≥ 30 gallons	$200
Texas	Austin Energy[34]	Water Heaters	New replacement	$100

3.2.5.6 Super-Efficient Gas Water Heating Appliance Initiative

The Super-Efficient Gas Water Heating Appliance Initiative (SEGWHAI) states that it “will develop and implement the next generation of cost-effective and high-efficiency storage-type gas water heater. SEGWHAI will facilitate the development and commercialization of this next generation of standard water heater. SEGWHAI will develop a well funded incentive program to make mass commercialization possible for gas storage water heater units that meet SEGWHAI performance specifications.”[35]

3.2.6 Historical Shipments

Annual product shipment trend data are an important aspect of the market assessment and development of the standards rulemaking. Such data are used in the shipments analysis (chapter 9). The number of unit shipments is expected to follow a trend similar to that of new home starts. However, the percentage of consumers with multiple units of some appliances is expected to rise, causing unit shipments of certain appliances to increase, or not to drop as quickly as they otherwise would have.

3.2.6.1 New Home Starts

Trends in new home starts may directly affect shipments of residential water heaters, direct heating equipment, and pool heaters. While there is a market for both replacement and remodeling for some of these products, residential water heaters are fixtures in virtually all new homes.

Figure 3.2.5 presents the number of new single-family and multifamily housing units started in the United States from 1990 to 2007. Between 2000 and 2005, single-family home starts increased 39.4 percent and peaked at 1,716,000 units annually. This trend reversed to a 63.8 percent decrease from 2005 to 2008, when home starts fell to 622,000 units.[1] The result is an overall decrease in new home starts of 51 percent between 2000 and 2008. Multifamily unit starts have remained relatively steady over the past 7 years, hovering around 350,000 units annually.[36]

[1] Fourth quarter 2008 data are preliminary.

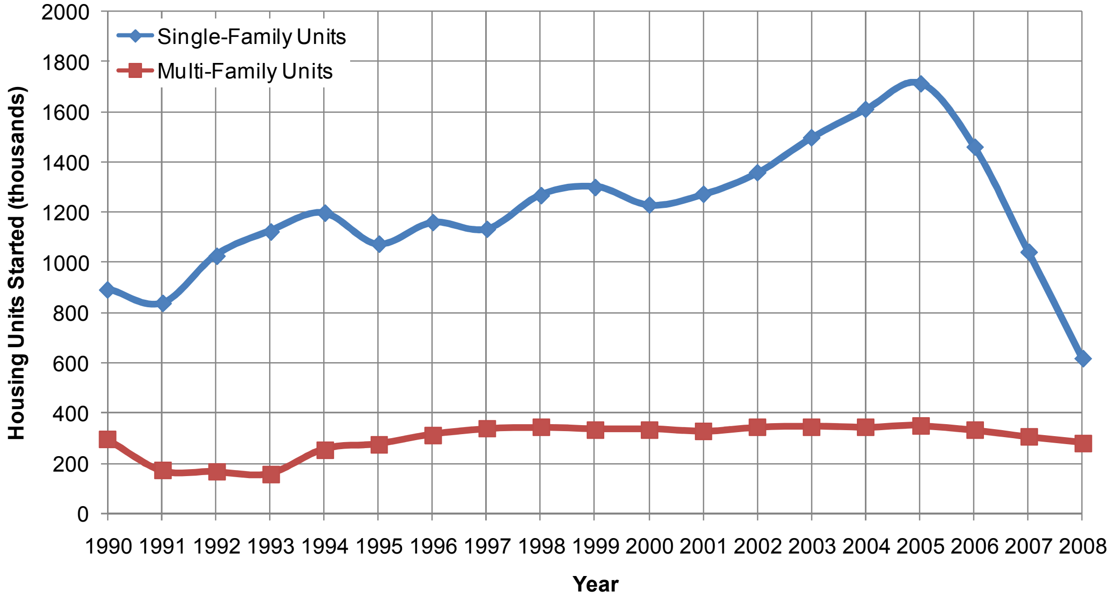


Figure 3.2.5 New Privately Owned Single-Family and Multifamily Housing Unit Starts in the United States, 1990-2008[37]

3.2.6.2 Shipments

Information about annual equipment shipment trends allows DOE to estimate the impacts of energy conservation standards on the residential water heater, direct heating equipment, and pool heater industries. DOE has examined unit shipments and value of shipments for residential water heaters, direct heating equipment, and pool heaters using publicly available data from the U.S. Census Bureau's Annual Survey of Manufacturers (ASM) and Current Industrial Reports (CIR), and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and AHRI estimates.

3.2.6.3 Water Heater Unit Shipments

The U.S. Census Bureau's annual CIR provides annual unit shipments and value of shipments for various industries, including the residential water heater industry. The CIR however, does not distinguish between shipments for new construction and replacement.

Figure 3.2.6 presents the annual shipments of residential water heaters (domestic and imported shipments) from 2001 to 2007 based on the annual CIRs.[38]

The numbers show two trends that affect the residential water heater industry. Overall, shipments of electric and non-electric water heaters have declined since 2001. However, shipments of non-electric water heaters have declined more rapidly than shipments of electric water heaters. In 2006 and 2007, shipments of electric water heaters exceeded shipments of non-electric water heaters.

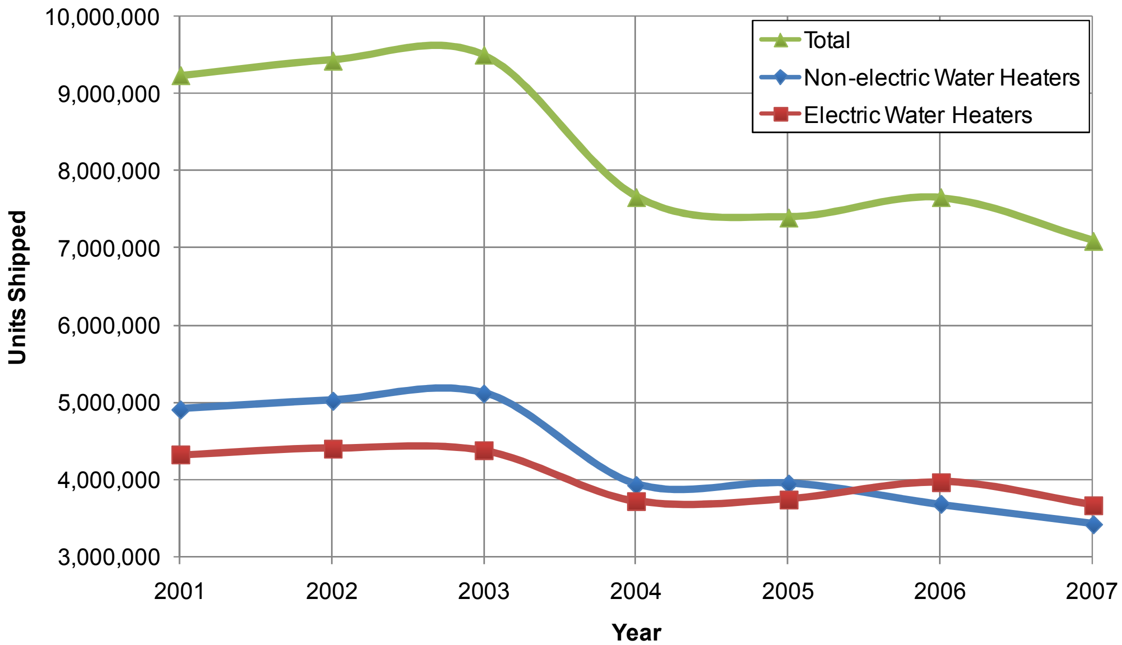


Figure 3.2.6 Residential Water Heater Industry Shipments (Domestic and Imported)[39]

Table 3.2.18 presents the annual shipments of the residential water heater industry from 2003 to 2007 as estimated by AHRI.

Table 3.2.18 AHRI Residential Water Heater Industry Estimated Shipment Data (New Construction and Replacement)*[40]

Year	Electric, Storage Water Heaters *units*	Gas, Storage Water Heaters *units*	Oil-Fired, Storage Water Heaters** *units*	Gas Instantaneous Water Heaters† *units*	Total *units*
2007	4,470,000	4,384,000	36,000	322,000	9,213,000
2006	4,792,000	4,654,000	33,000	242,000	9,720,000
2005	4,519,000	4,993,000	38,000	156,000	9,707,000
2004	4,573,000	5,246,000	34,000	85,000	9,938,000
2003	4,430,000	5,124,000	36,000	N/A	9,590,000

* Shipments rounded to nearest 1,000 units.
** Only showing shipments for 30- and 32-gallon models.
† Shipment data not available for all years.

3.2.6.4 Water Heater Value of Shipments

Table 3.2.19 provides the value of shipments for the residential water heater industry from 2000 to 2007 using the U.S. Census Bureau CIRs.[41] The CIR expresses all dollar values in current dollars (*i.e.*, 2003 data are expressed in 2003$, etc.). Using the Gross Domestic Product (GDP) Deflator, DOE converted each year's shipment values to 2009$; 2007 was the last year included in the CIR data set.

Table 3.2.19 Residential Water Heater Value of Shipments by Year[42]

Year	Value of Shipments *$ millions*			Value of Shipments in 2009$ *$ millions*		
	Non-Electric	**Electric**	**Total**	**Non-Electric**	**Electric**	**Total**
2007	863.0	622.5	1485.5	891.9	643.4	1,535.3
2006	902.8	651.9	1,554.7	959.8	693.1	1,652.9
2005	970.2	638.4	1,608.6	1,065.1	700.8	1,765.9
2004	884.1	545.3	1,429.4	1,002.9	618.6	1,621.5
2003	985.6	569.5	1,555.1	1,149.8	664.4	1,814.2
2002	842.0	576.0	1,418.0	1,003.4	686.4	1,689.8
2001	799.3	555.7	1,355.0	968.0	673.0	1,640.9
2000	843.6	572.7	1,416.3	1,044.7	709.2	1,753.9

According to the data, non-electric and electric water heaters have had a relatively constant value of shipments between 2000 and 2007. Although the number of electric water heater shipments exceeded the number of non-electric water heater shipments in 2006, the value of non-electric water heater shipments continued to exceed the value of electric water heater shipments even as the number of non-electric water heater shipments declined.

3.2.6.5 Direct Heating Equipment Shipments

The direct heating industry does not report information about direct heating equipment shipments in as much detail as the water heater industry due to confidentiality concerns. DOE received shipment data from AHRI on traditional types of direct heating equipment (*i.e.*, wall furnaces, floor furnaces, and room heaters). Information is not available for every year, and some information was omitted to preserve confidentiality. Generally, the traditional direct heating product industry had small sales volumes and a decline in shipments. Some products (*e.g.*, floor furnaces) are sold strictly as replacement products. Expansion of the consumer base to increase shipments is unlikely because in recent years more consumers are installing central heating systems instead of using direct heating methods to heat their homes. In contrast, there are much higher shipment volumes for gas hearth DHE, which are installed in new construction. Gas hearth DHE are desirable because of their aesthetic appeal in addition to their heating capabilities. DOE obtained the shipments data for gas-fired fireplaces from HPBA.[43]

Table 3.2.20 presents the annual shipments of the residential direct heating equipment industry from 2002 to 2006 as estimated by AHRI and HPBA.

Table 3.2.20 AHRI and HPBA Residential Direct Heating Equipment Industry Estimated Shipment Data (New Construction and Replacement)*[44]

Year	Vented Wall Furnace**	Direct Vent Wall Furnace**	Floor Furnaces	Vented Room Heaters***	Vented Gas Hearth DHE[††,†††]
2006	28,800	104,800	3,800	N/A	1,727,700
2005	33,500	112,900	4,400	18,307	2,141,200
2004	30,500	123,200	4,500	20,950	2,103,700
2003	29,300	121,200	5,100	23,300	1,809,800
2002	26,800	117,600	5,600	21,200	1,716,100

* Shipment totals are rounded to nearest 100 units.
** Not specific to only fan-type or gravity-type direct heating equipment.
*** Shipment data not available for all years.
† Includes certain fireplaces that are AHRI certified
†† Shipment data from HPBA.
†††Includes gas log sets and decorative products, which are not covered products.

3.2.6.6 Pool Heater Shipments

The pool heater industry does not report information about pool heater shipments in as much detail as the water heater industry due to confidentiality concerns. However, in response to the NOPR analysis, APSP provided DOE with shipment information in the form of a written comment, and the shipment data for pool heaters from 2003 to 2009 is shown in Table 3.2.21.

Table 3.2.21 Residential Gas-Fired Pool Heater Shipments

Year	Pool Heater Shipments
2009	118,000
2008	161,000
2007	185,000
2006	215,000
2005	232,000
2004	193,000
2003	168,000

3.2.7 Industry Cost Structure

DOE developed the residential water heater, direct heating equipment, and pool heater industry cost structures from publicly available information from the ASM, and from Security Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers. Companies subject to SEC regulations must report sales, costs of goods sold, gross profits, and various overhead costs, in addition to overall performance and operations for the year. DOE analyzed SEC reports and developed a representative cost structure for the industries of each product type.

DOE examined SEC 10-K reports from 2000 to 2006. The cost of materials as a percentage of revenue for each product can fluctuate as raw material costs change from year to year. The cost of payroll for production workers as a percentage of revenue for each product type has declined, pointing to the possibility of increased production automation in the heating products industry. Finally, selling, general, and administrative costs have declined as manufacturers cut costs by reducing the non-production, support, and administrative employee base.

Table 3.2.22 presents the industry cost structure derived from the SEC 10-K reports.[m] Each financial statement entry is presented as a percentage of total revenue.

Table 3.2.22 Industry Cost Structure Using SEC Data

Financial Statement Entry	Percent of Total Revenue for Each Product Type		
	Water Heaters	Direct Heating Equipment	Pool Heaters
Profit before Financing	6.0	9.2	7.2
Selling, General, and Administrative Expenses	14.0	12.5	16.0
Research and Development	2.1	2.0	2.5
Overhead	15.4	16.0	16.0
Labor	10.1	9.4	10.0
Material	52.4	50.9	48.3
Total	100.0	100.0	100.0

The manufacturer impact analysis (MIA) (chapter 12 of this TSD) presents a detailed financial analysis of each of the three product types covered by this rulemaking. This analysis identifies key financial inputs, such as the cost of capital, working capital, depreciation, and capital expenditures.

3.2.8 Equipment Lifetime

DOE reviewed available literature and consulted with manufacturers to establish typical equipment lifetimes. (See the life-cycle cost analysis, chapter 8 of this TSD, for additional details and sources used to determine the typical equipment lifetimes.) DOE combined these sources to develop average estimated lifetimes of the equipment covered by this rulemaking (Table 3.2.23).

[m] For more information, please visit www.sec.gov.

Table 3.2.23 Equipment Lifetimes

Equipment	Average Lifetime *years*
Residential Water Heaters	
Gas Storage-Type Water Heater	13
Oil-Fired Water Heater	13
Electric Storage-Type Water Heater	13
Gas Instantaneous Water Heater	20
Direct Heating Equipment	
Traditional and Hearth Direct Heating Equipment	15
Pool Heaters	
Gas Pool Heater	10

Chapter 8 of the TSD provides more information about residential water heater, direct heating equipment, and pool heater lifetimes.

3.2.9 Market Performance Data

DOE combined information from the AHRI directory,[45] the CEC,[46] and the FTC with other publicly available data from manufacturers' catalogs of residential water heaters, direct heating equipment, and pool heaters to develop an understanding of these industries and their markets. These databases contain information such as manufacturer name, model number, and efficiency.

3.2.9.1 Residential Water Heaters

Figure 3.2.7 through Figure 3.2.18 show the distribution of energy factors and capacities of gas storage, oil-fired storage, electric storage, and instantaneous gas water heaters in the AHRI directory. DOE created separate market performance plots for ultra low NO_X gas storage water heaters because currently available ultra low NO_X gas storage water heaters exhibit difference performance characteristics than gas storage water heaters with a standard burner, due primarily to reduced air flow. Ultra low NO_X burners are required on water heaters in certain areas of the United States that restrict nitrous oxide emissions of certain consumer appliances. Consequently, in the engineering analysis, DOE analyzed two representative gas storage water heaters—one with a standard burner and one with an ultra low NO_X burner. (See chapter 5 of the TSD for more details.)

Figure 3.2.7 shows the number of gas storage water heaters at each energy factor rating from 0.48 to 0.67. The figure contains data for all volumes of storage capacity.

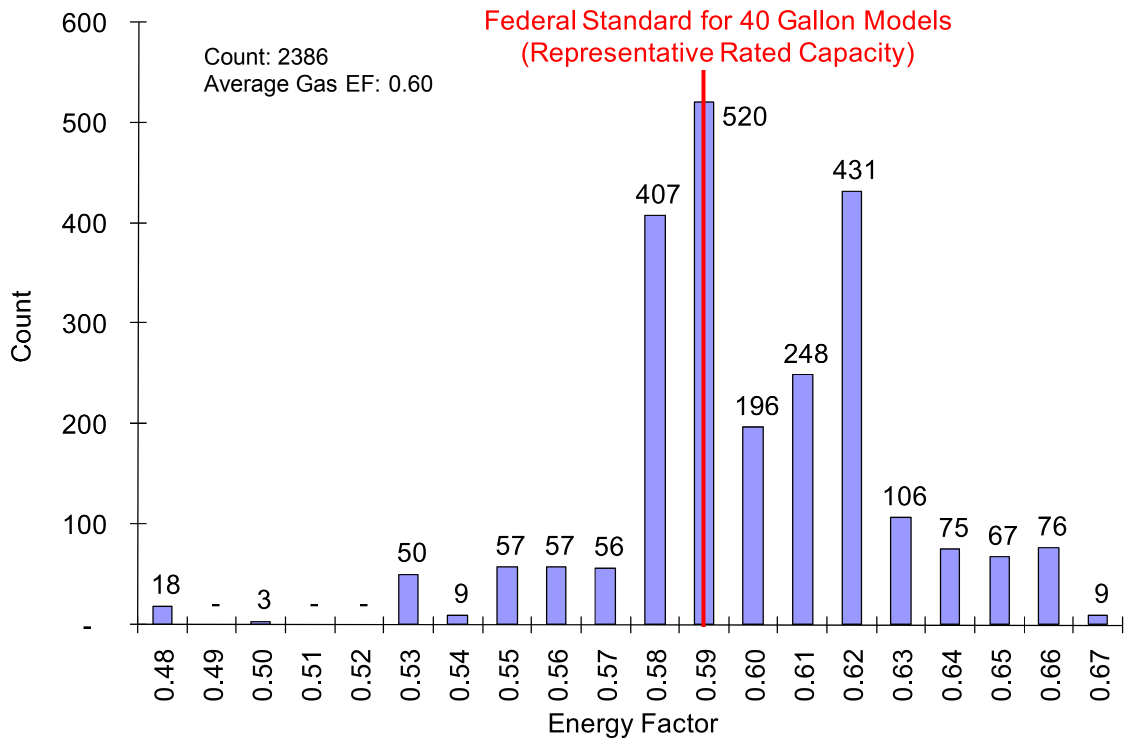


Figure 3.2.7 Distribution of Gas Storage-Type Water Heater Models by Energy Factor for All Storage Volumes, All Burner Types

Gas-fired water heater energy factors are concentrated between 0.58 and 0.63 EF. The minimum standard level listed in Figure 3.2.7 represents the Federal standard for a 40-gallon gas water heater, the representative volume for gas water heaters. Chapter 5 of the TSD discusses the analysis of the representative volume.

Figure 3.2.8 shows the number of gas-fired storage water heaters at each rated storage volume.

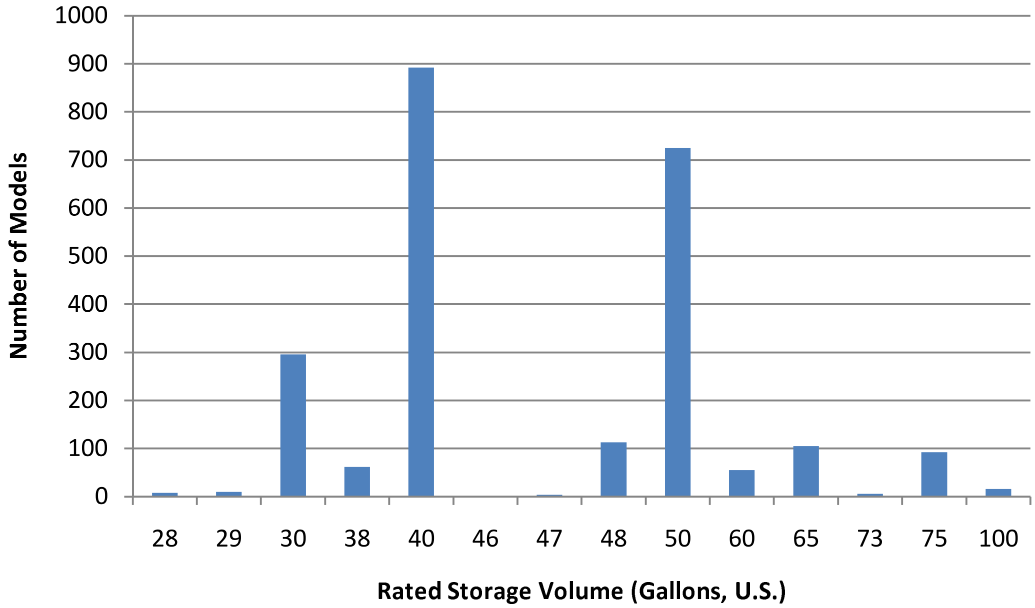


Figure 3.2.8 Distribution of Gas-fired Storage Water Heater Models by Rated Storage Volume, All Burner Types

Gas-fired storage water heaters are mainly concentrated at the 40 and 50 gallon storage volumes. Based on the "large" and "small" product class division used for TSL 5 (*i.e.*, water heaters above 55 gallons are classified as "large" and all others are classified as "small"), 11.5% of gas-fired storage water heater models would fall into the "large" category and 88.5% of gas-fired storage water heater models would be considered "small."

Figure 3.2.9 shows the distribution of efficiencies at various capacities for gas-fired storage water heaters and how the Federal standard, defined by energy factor, relates to rated storage capacity based on the equation in Table 3.2.8.

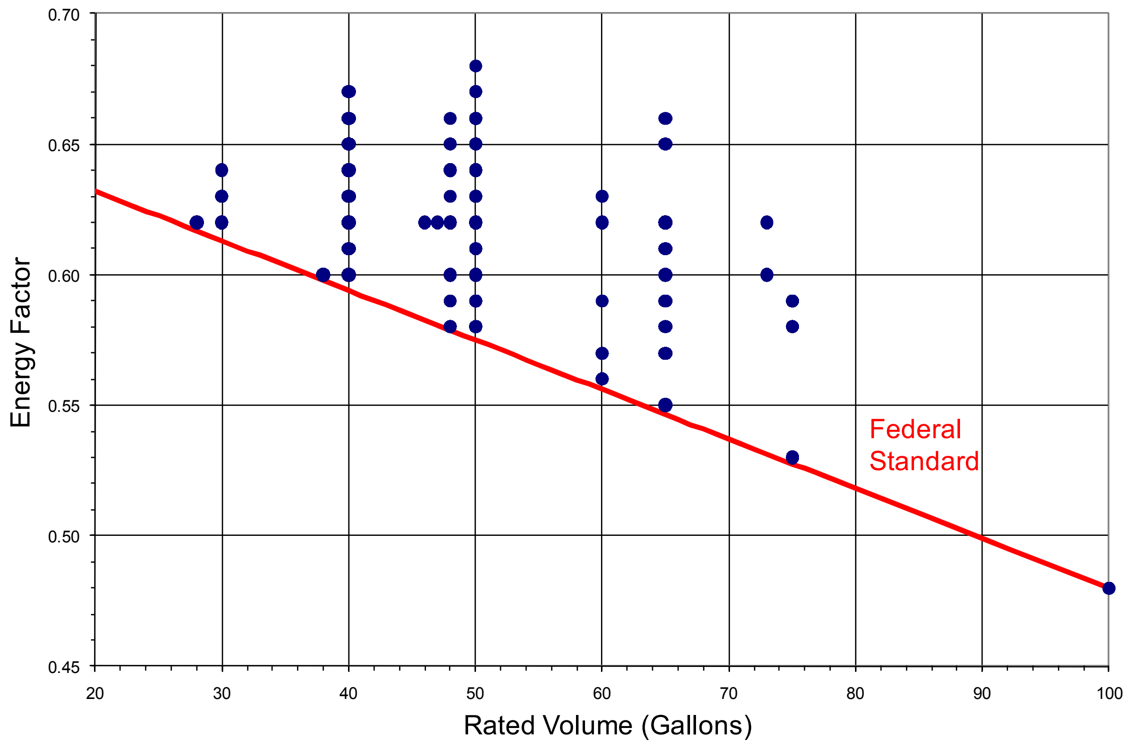


Figure 3.2.9 Distribution of Gas-Fired Storage-Type Water Heater Models by Storage Capacity, All Burner Types

Gas-fired water heaters are mainly distributed between 30 and 75 gallons of storage capacity. Generally, energy factor decreases as storage capacity increases due to increased standby losses at higher gallon sizes.

Figure 3.2.10 shows the number of ultra low NO_X gas-fired storage water heaters at each energy factor rating, from the minimum rating on the market of 0.56 to the maximum available rating of 0.62. The figure contains data for the all volumes of storage capacity.

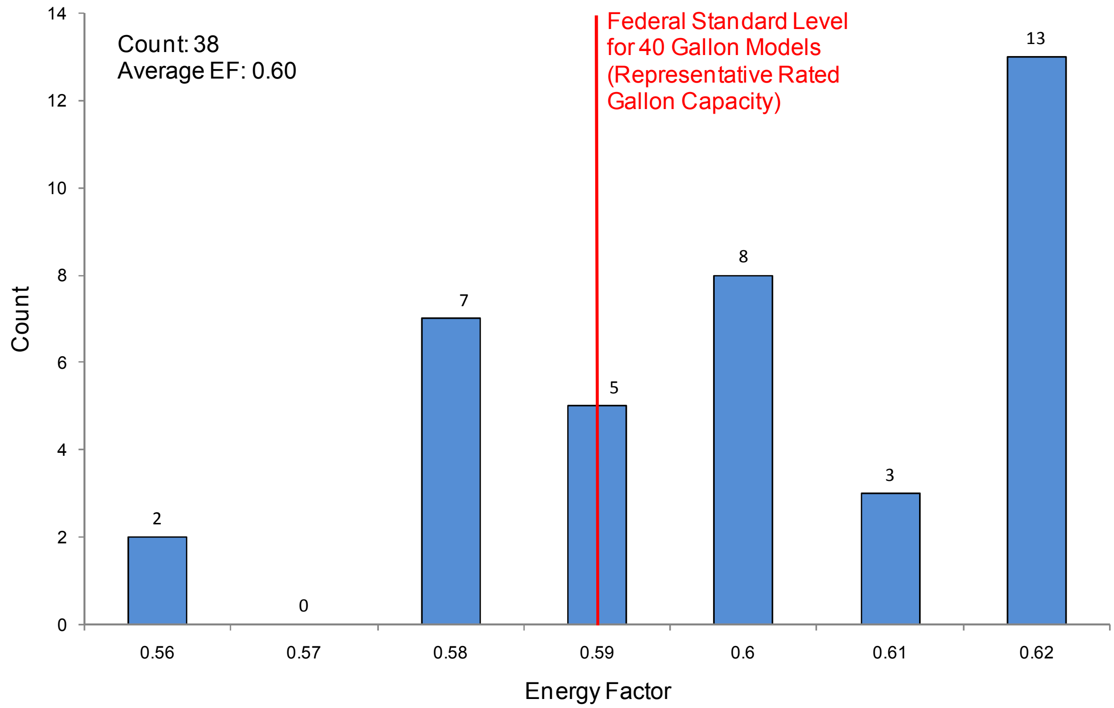


Figure 3.2.10 Distribution of Ultra Low NO_X Gas-Fired Storage-Type Water Heater Models by Energy Factor for All Storage Volumes

Ultra low NO_X gas-fired water heater energy factors are concentrated between 0.58 and 0.62 EF. The minimum standard level listed in Figure 3.2.10 represents the Federal standard for a 40-gallon gas-fired water heater, the representative volume for gas-fired water heaters.

Figure 3.2.11 shows the distribution of efficiencies at various capacities for ultra low NO_X gas-fired storage water heaters, and how the Federal standard, defined by energy factor, relates to rated storage capacity based on the equation in Table 3.2.8.

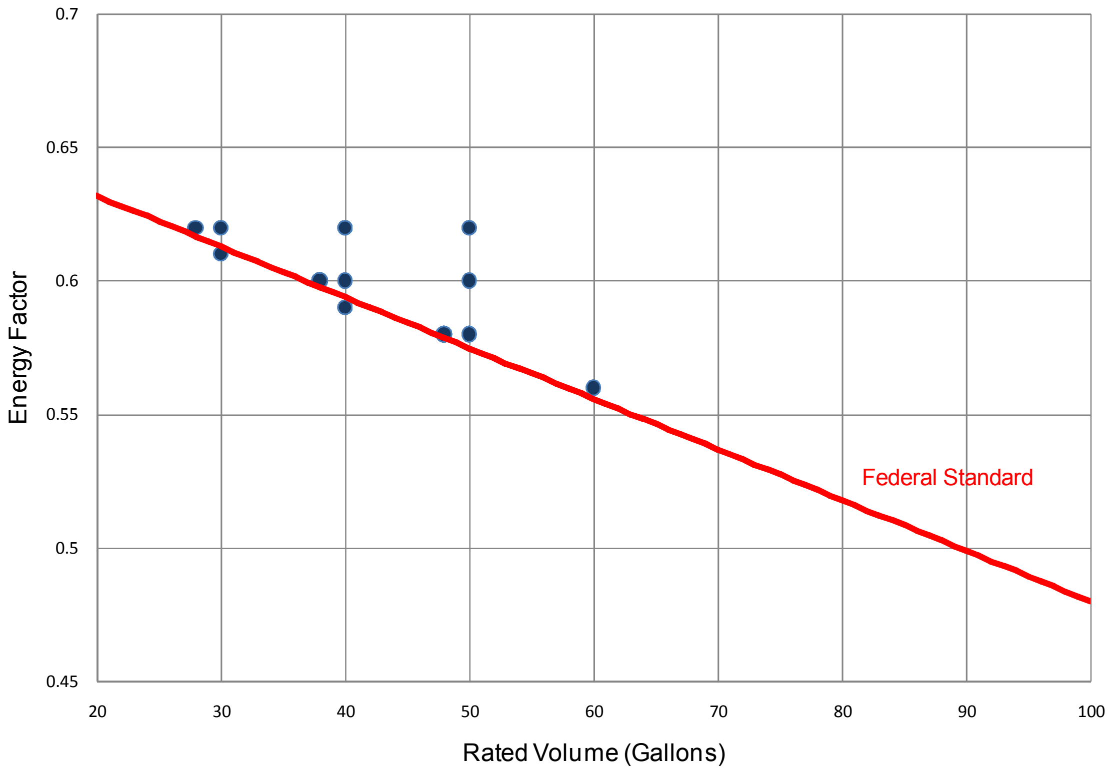


Figure 3.2.11 Distribution of Ultra Low NO_X Gas-Fired Storage Water Heater Models by Storage Capacity

Ultra low NO_X gas-fired water heaters are mainly distributed between 30 and 60 gallons of storage capacity. Generally, energy factor decreases as storage capacity increases.

Figure 3.2.12 shows the distribution of electric storage water heater models by energy factor for all storage volumes.

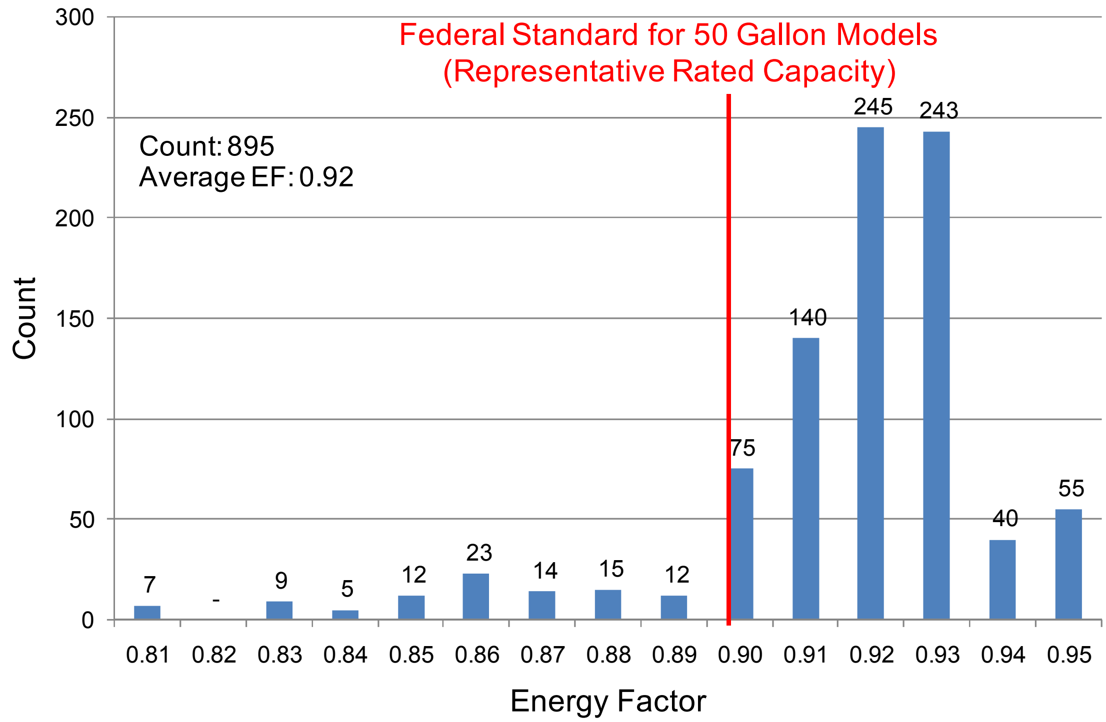


Figure 3.2.12 Distribution of Electric Resistance Storage Water Heater Models by Energy Factor for All Storage Volumes (Excludes Heat Pump Water Heaters)

Electric water heater energy factors are concentrated between 0.90 and 0.93. The Federal standard level listed in Figure 3.2.12 represents the current Federal standard for a 50-gallon electric water heater, the representative volume for electric water heaters. Heat Pump Water Heaters are also available that have EFs ranging from 2.0 to 2.5 EF. Figure 3.2.14 below shows those models. Chapter 5 of the TSD discusses the analysis of the representative volume.

Figure 3.2.13 shows the distribution of electric storage water heaters at each storage volume.

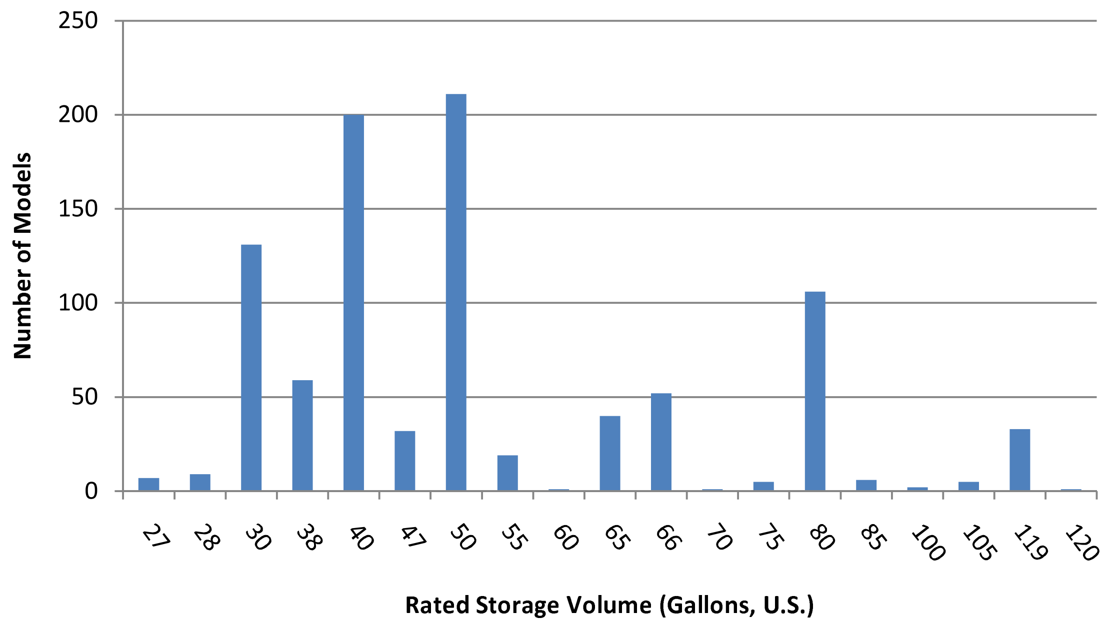


Figure 3.2.13 Distribution of Electric Storage Water Heater Models by Rated Storage Volume

Electric storage water heaters are concentrated primarily at the 40 and 50 gallon storage volumes. Based on the "large" and "small" product class division used for TSL 5 and TSL 6 in the final rule (i.e., storage water heaters above 55 gallons are classified as "large" and all others are classified as "small"), 27.4% of electric storage water heater models would fall into the "large" category and 72.6% of electric storage water heater models would be considered "small."

Figure 3.2.14 shows another distribution of models and how the Federal standard, defined by energy factor, relates to rated storage capacity based on the equation in Table 3.2.8.

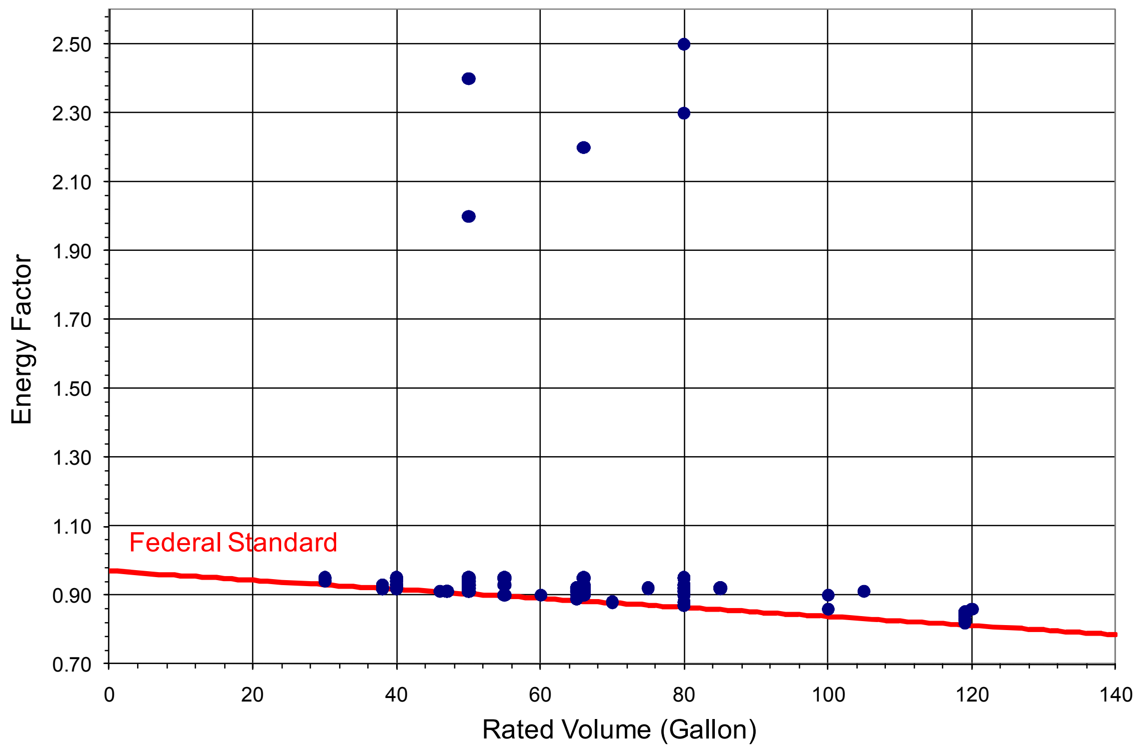


Figure 3.2.14 Distribution of Electric Storage-Type Water Heater Models by Storage Capacity

Figure 3.2.14 shows an obvious trend of electric storage water heater efficiency decreasing as storage capacity increases for units using electric resistance technology (*i.e.*, EF between 0.80 and 0.95). There is a wide variety of electric storage water heater volume capacities available to consumers, from 27 to 120 gallons. Also, Figure 3.2.14 shows several heat pump water heater models that achieve EFs well above those achieved using electric resistance technology (*i.e.*, greater than 1.0 EF). Heat pump water heaters are available in storage sizes ranging from 50 to 80 gallons.

Figure 3.2.15 shows the distribution of oil-fired storage water heater models by energy factor and storage capacity for all storage volumes.

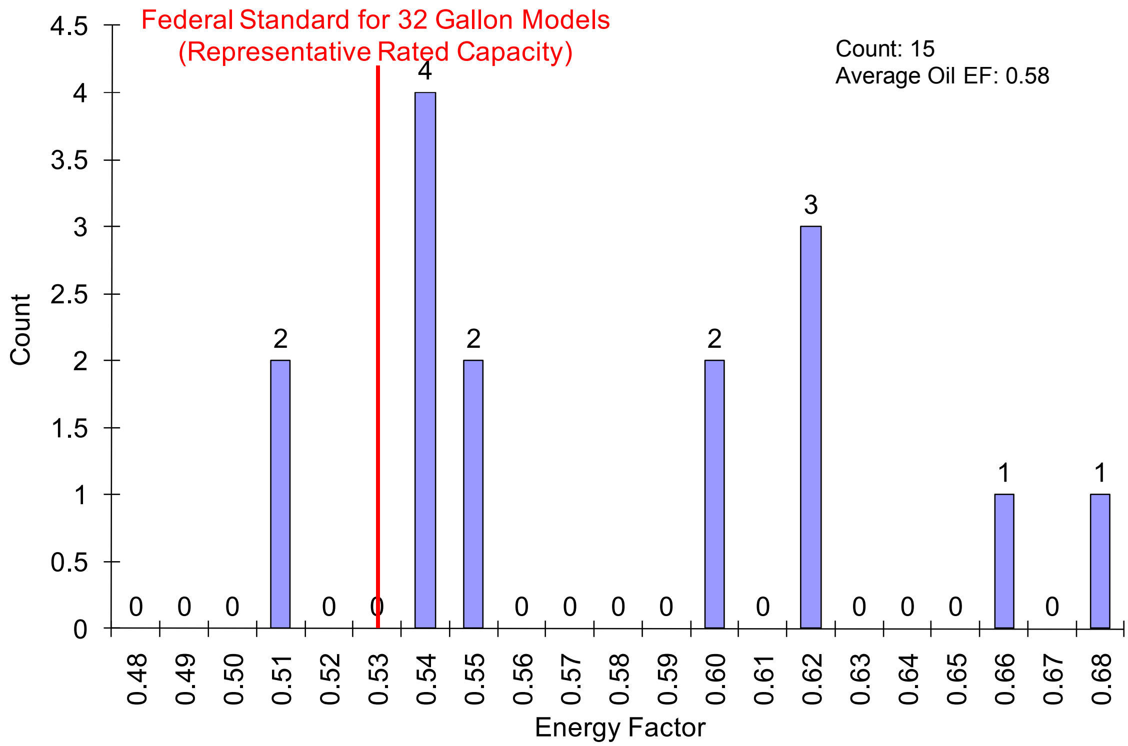


Figure 3.2.15 Distribution of Oil-Fired Storage-Type Water Heater Models by Energy Factor for All Storage Volumes

Oil-fired water energy factors are more diffuse. The Federal standard level listed on Figure 3.2.15 represents the current Federal standard for a 32-gallon oil-fired water heater, the representative volume for oil-fired water heaters. Chapter 5 of the TSD discusses the analysis of the representative volume.

Figure 3.2.16 shows another distribution of the oil-fired storage water heater models and how the Federal standard, defined by energy factor, relates to rated storage capacity based on the equation in Table 3.2.8.

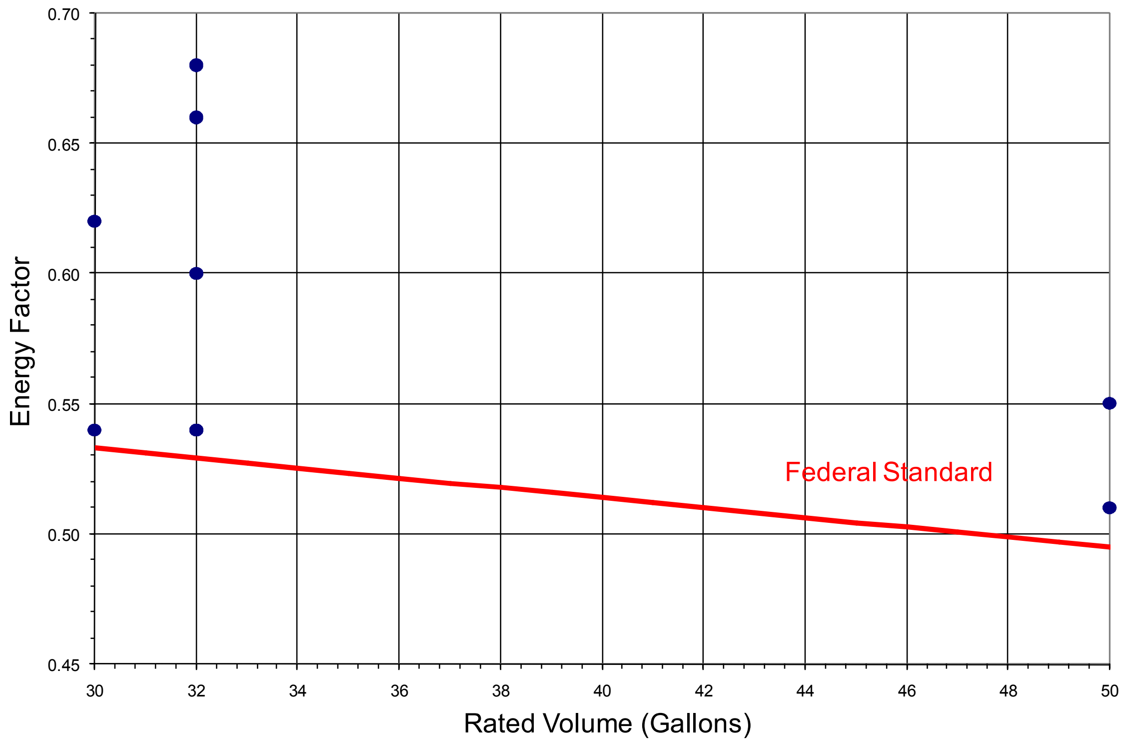


Figure 3.2.16 Distribution of Oil-Fired Storage-Type Water Heater Models by Storage Capacity

Figure 3.2.16 shows that oil-fired storage water heaters are concentrated around 30 to 32 gallons and 50 gallons of storage capacity. The energy factor decreases as volume increases.

Figure 3.2.17 shows the distribution of energy factors of instantaneous gas-fired water heaters in the AHRI, CEC, and FTC directories.

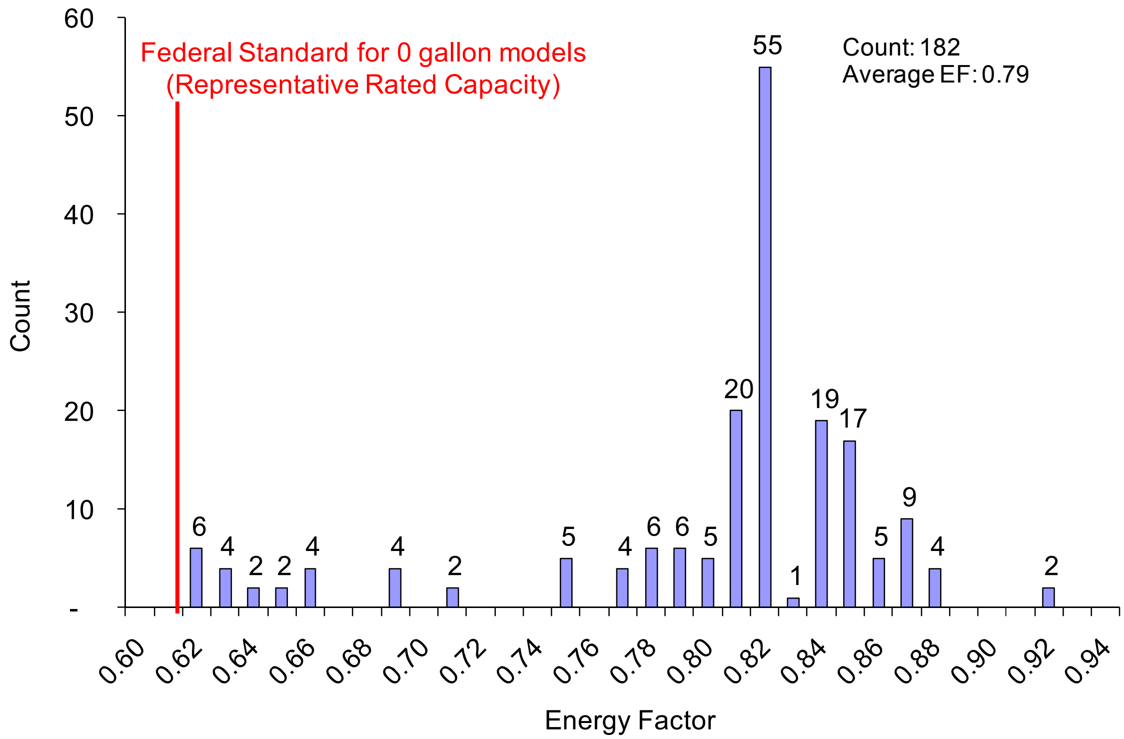
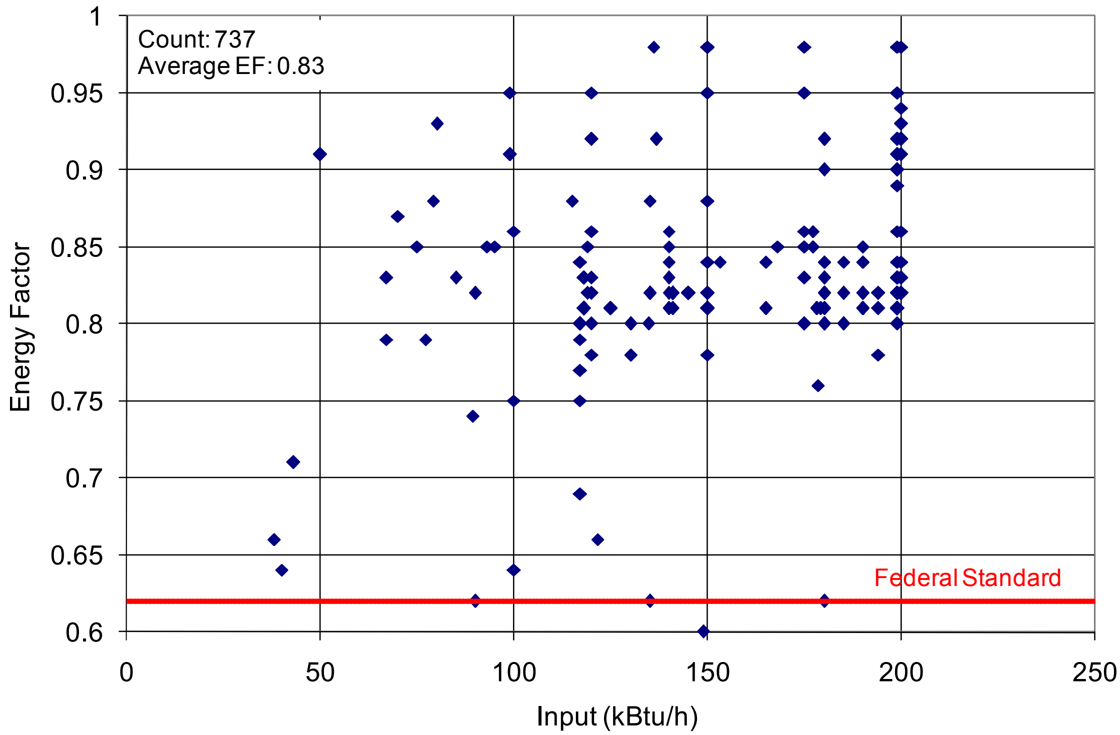


Figure 3.2.17 Distribution of Instantaneous Gas-Fired Water Heater Models by Energy Factor, All Input Capacity Ratings

The instantaneous gas-fired water heater market is concentrated around units with energy factors ranging from 0.80 to 0.84. Figure 3.2.18 shows another distribution of instantaneous gas-fired water heaters and how energy factors relate to input capacity. The Federal standard line is based on the equation in Table 3.2.8 for existing Federal energy conservation standards. The line is horizontal because energy factor does not depend on input capacity and because the rated storage volume for all instantaneous water heaters is 0 gallons.



Count: 737
Average EF: 0.83
Energy Factor
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
Federal Standard
0
50
100
150
200
250
Input (kBtu/h)

Figure 3.2.18 Distribution of Instantaneous Gas-Fired Water Heater Models by Input Capacity

3.2.9.2 Direct Heating Equipment

Figure 3.2.19, Figure 3.2.20, Figure 3.2.21, Figure 3.2.22 and

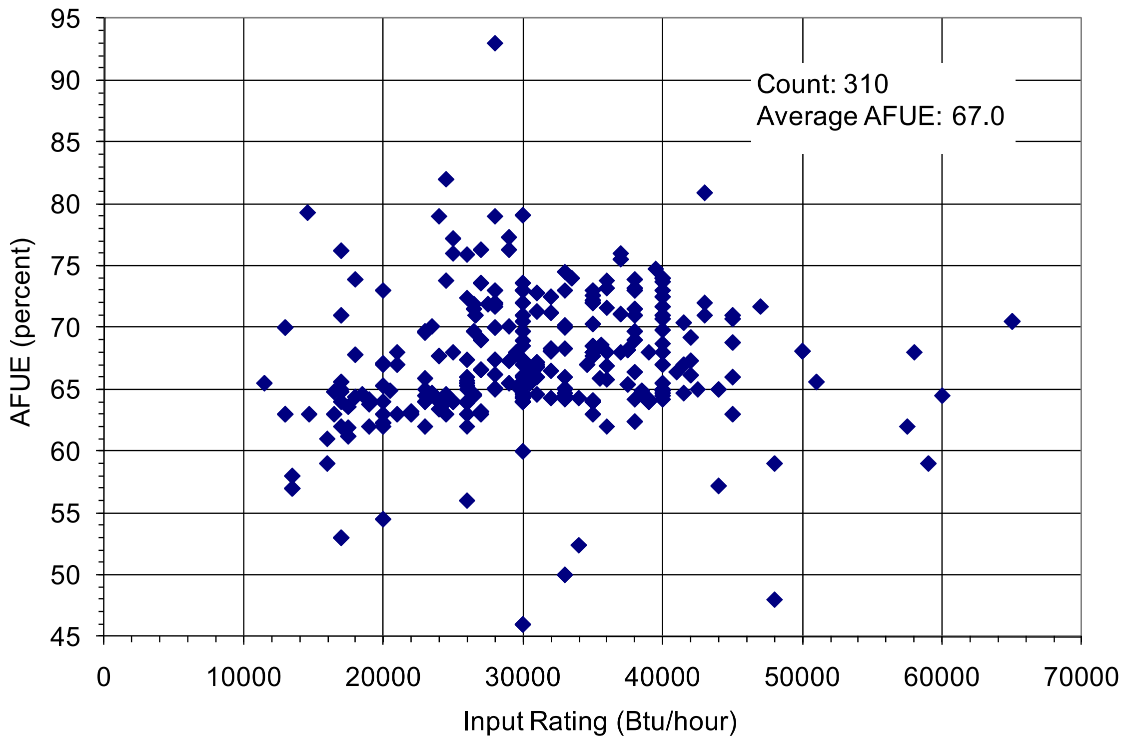


Figure 3.2.23 show the input rating and AFUE of wall furnace fan-type, wall furnace gravity-type, floor furnace, room heater, and hearth-type direct heating equipment, respectively. DOE obtained this information from the AHRI directory and other publicly available product literature.

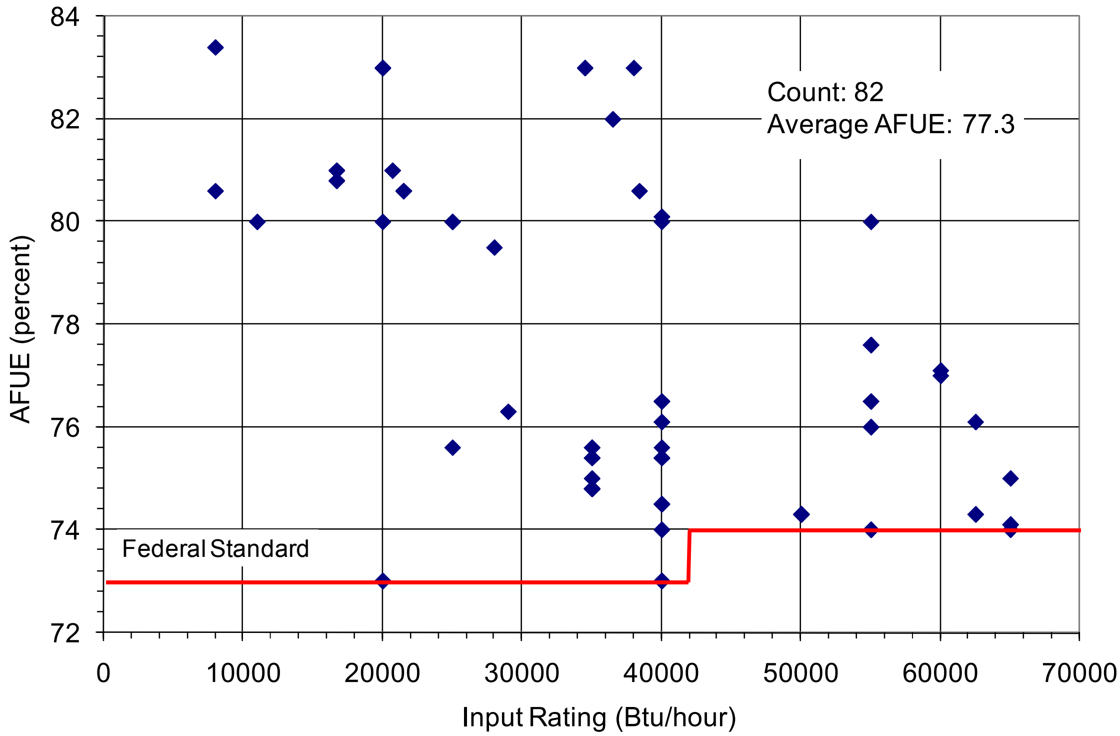


Figure 3.2.19 Distribution of Wall Fan Models by Input Rating and AFUE

Some fan-type wall furnaces just meet the Federal standard, while some exceed the Federal standard by more than 10 absolute percentage points. There is no concentration of efficiencies. When fan-type wall furnaces are analyzed by input rating, efficiency varies across the range of AFUEs. For low-efficiency products, efficiency increases with increased input rating. For high-efficiency products, efficiency decreases with increased input rating.

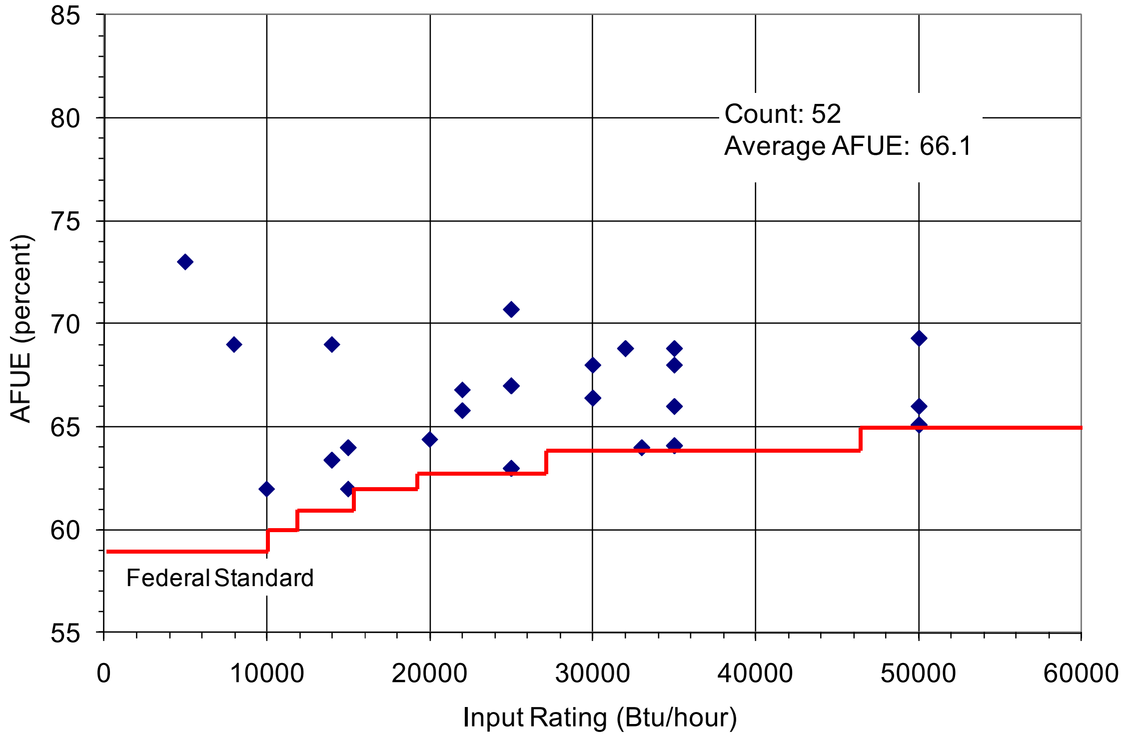


Figure 3.2.20 Distribution of Wall Gravity Models by Input Rating and AFUE

Some gravity-type wall furnaces just meet the Federal standard, while some exceed the Federal standard by more than 20 absolute percentage points. The majority of gravity-type wall furnaces have efficiencies below 70 percent AFUE. There is no discernible relationship between input rating and efficiency.

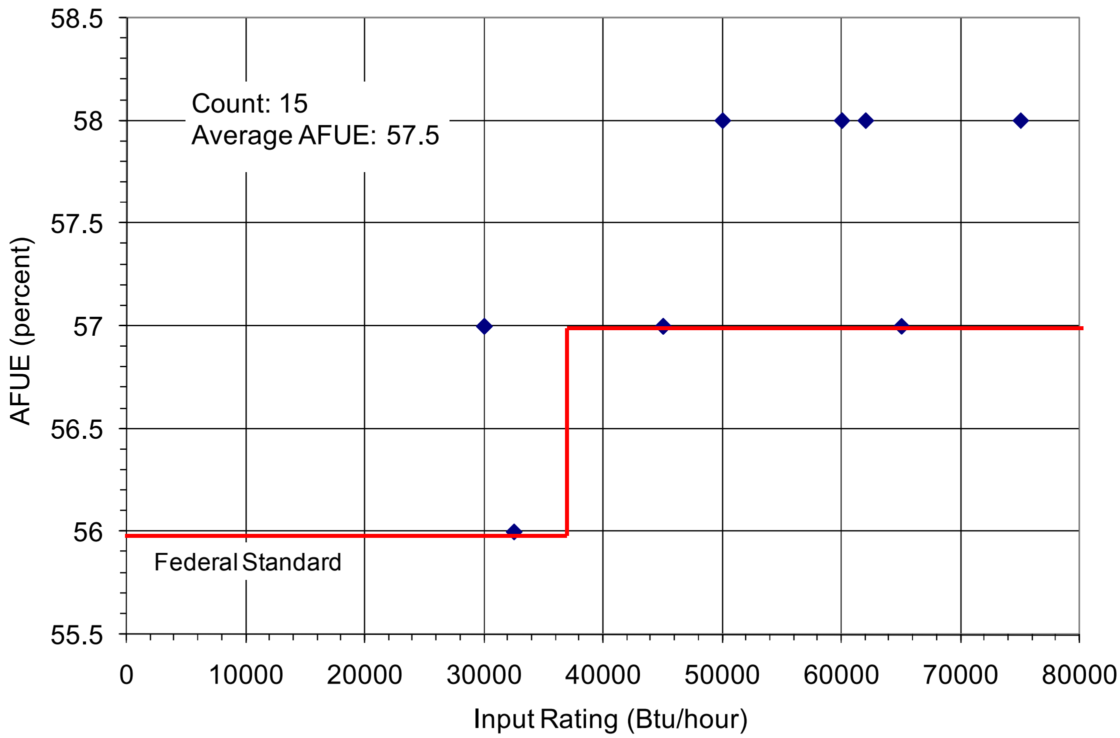


Figure 3.2.21 Distribution of Floor Furnace Models by Input Rating and AFUE

Some floor furnaces just meet the Federal standard, while some exceed the Federal standard by only one absolute percentage point. Floor furnaces have efficiencies in a narrow range between 56 and 58 percent AFUE, with an increase in efficiency as input rating increases.

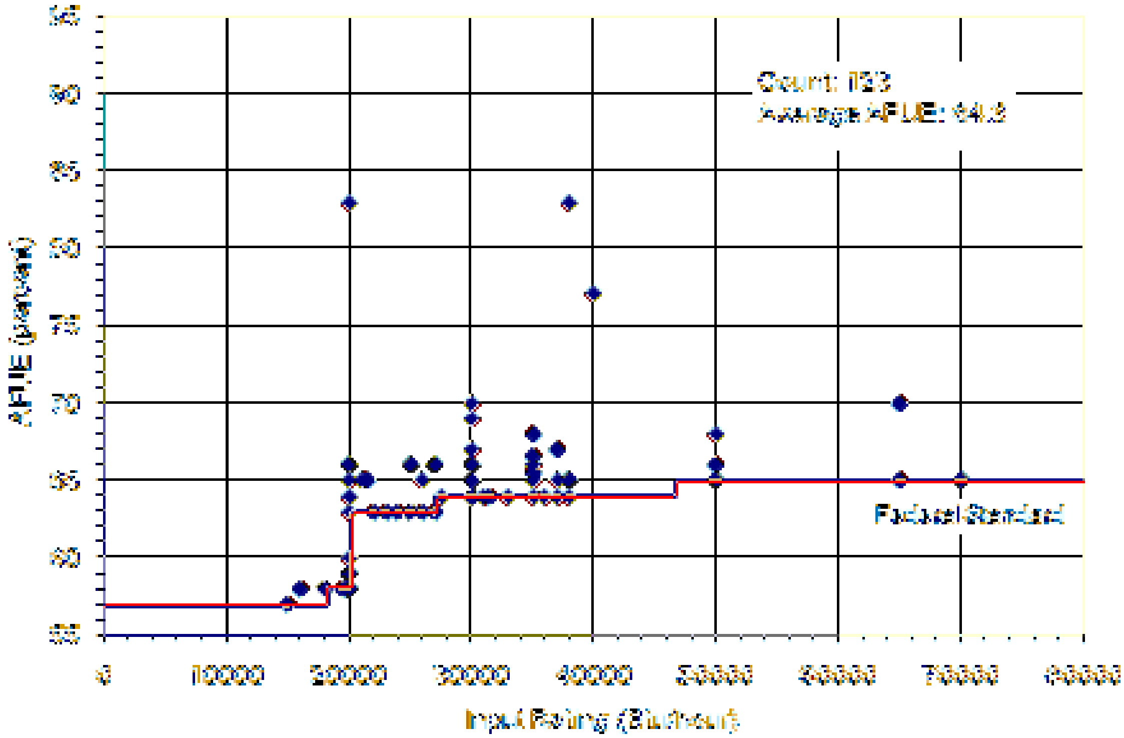


Figure 3.2.22 Distribution of Room Heater Models by Input Rating and AFUE

Some room heaters just meet the Federal standard, while some exceed the Federal standard by approximately 25 absolute percentage points or more. Room furnaces have efficiencies in a range between 57 and 83 percent AFUE, with an increase in efficiency as input rating increases. The room heaters rated at 83 percent AFUE were identified by DOE through review of publicly available product literature. Although AHRI does not list this product in its directory, it is available to consumers.

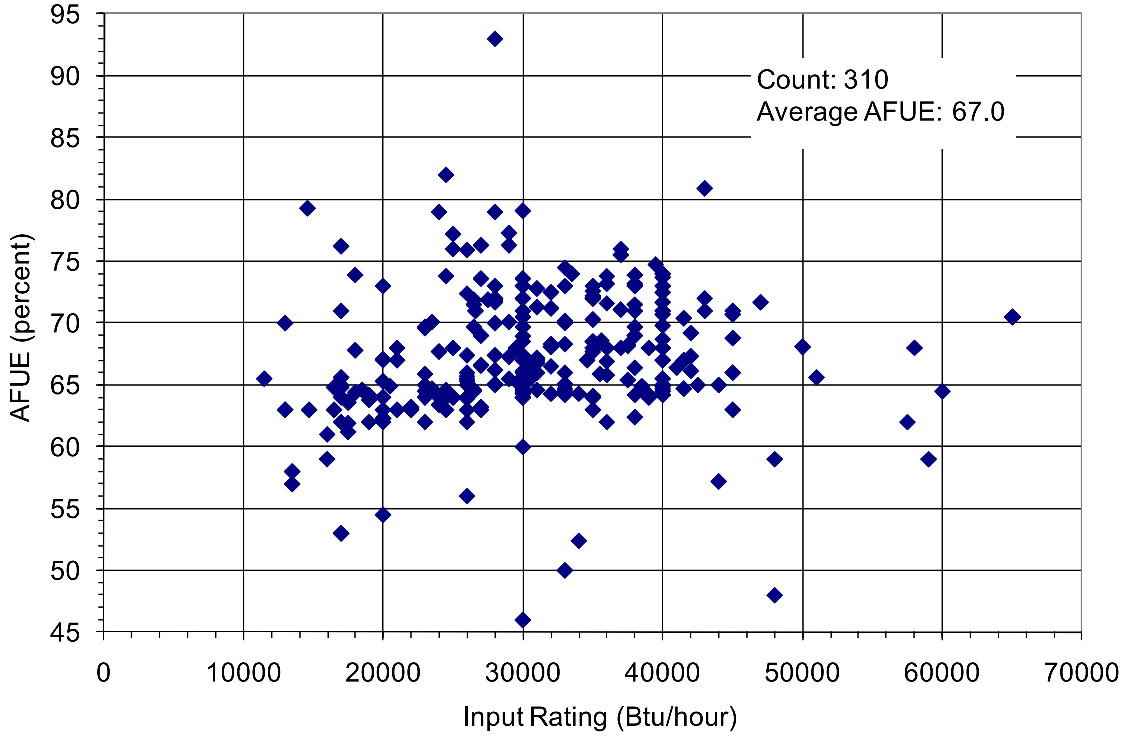


Figure 3.2.23 Distribution of Hearth Models by Input Rating and AFUE

Hearth models have efficiencies between 46 and 93 percent AFUE. AHRI does not list gas hearth DHE in its directory as a separate product type, but does include certain certified gas hearth DHE listed as various types of traditional direct heating equipment. DOE identified products currently in the AHRI database that would be classified as gas hearth DHE and separated them into their own product class. DOE found through a review of product literature that additional gas hearth DHE models are available to consumers, and DOE identified the AFUE ratings of these models based on manufacturer literature.

3.2.9.3 Pool Heaters

Figure 3.2.24 shows the distribution and thermal efficiency of gas-fired pool heaters in the CEC and FTC directories.

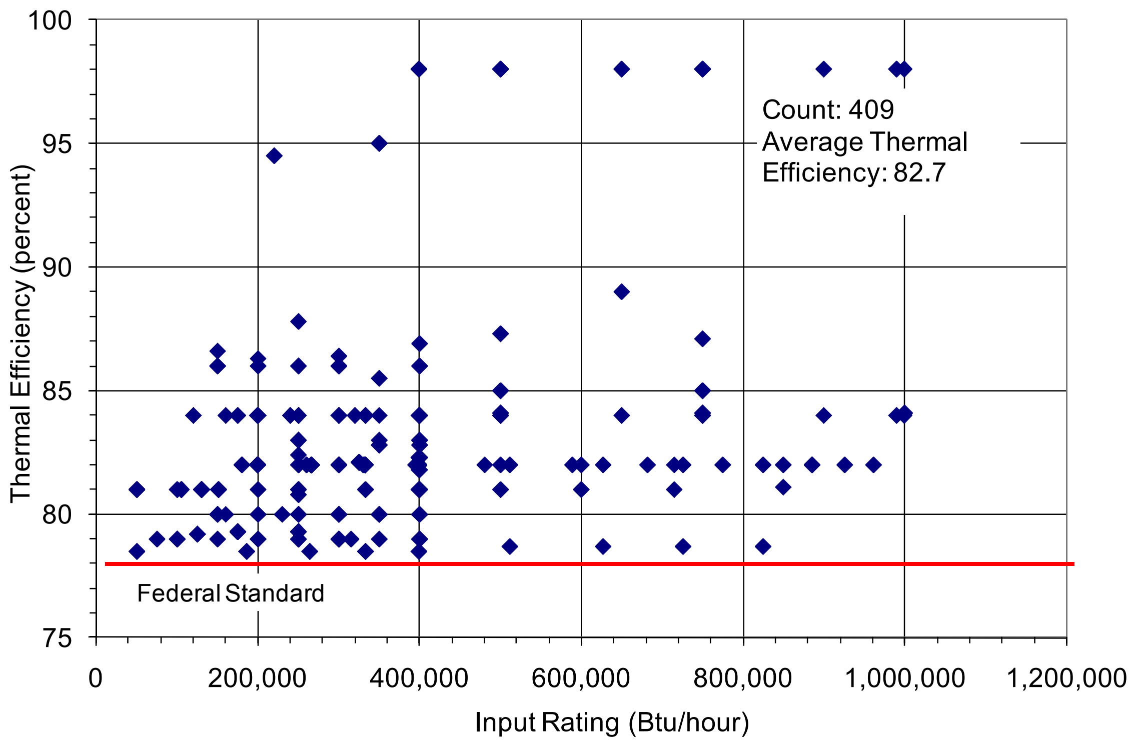


Figure 3.2.24 Distribution of Pool Heater Models by Input Capacity and Thermal Efficiency

The majority of pool heaters are rated with an input capacity of 400,000 Btu/h or less. Of these pool heaters, all models exceed the Federal standard. The pool heaters rated at input capacities above 400,000 Btu/h are typically not marketed for residential use.

3.3 TECHNOLOGY ASSESSMENT

The purpose of the technology assessment is to develop a list of technology options manufacturers can use to improve the efficiency of residential water heaters, direct heating equipment, and pool heaters. The following assessment provides descriptions of those technology options that apply to all product classes.

In preparation for the screening and engineering analyses, DOE identified several possible technology options and examined the most common efficiency-improving technologies used today. These technology options provide insight into the technological improvements typically used to increase the energy efficiency of residential water heaters, direct heating equipment, and pool heaters.

3.3.1 Baseline Equipment Components and Operation

The baseline model for each product class serves as a reference point for measuring changes resulting from energy conservation standards. DOE defines the baseline model in each product class as a product having an efficiency that just meets the existing Federal energy conservation standards. DOE also defines baseline models as having commonly available features.

3.3.1.1 Baseline Residential Water Heaters

Gas-Fired Storage Water Heaters. The baseline gas-fired storage water heater is a water heater that incorporates a complete gas-fired water heating system in an individual package. Each baseline gas-fired water heater consists of a glass-lined corrosion-resistant steel tank, insulation surrounding the top and sides of the tank, a dip tube that directs cold entering water to the bottom of the tank, a hot water outlet pipe, heat traps, a gas burner, a standing pilot ignition, a combustion chamber, a burner control thermostat, a gas valve, a sacrificial anode, a flue within the water tank, a baffle-type heat exchanger within the flue, a temperature and pressure-relief valve, an outer case, and packaging for shipment. Manufacturers may differentiate gas-fired water heaters by efficiency rating, input to burners, and storage capacity.

Oil-Fired Storage Water Heaters. The baseline oil-fired storage water heater is a water heater that incorporates a complete oil-fired water heating system in an individual package. Each baseline oil-fired water heater consists of a glass-lined corrosion-resistant steel tank, insulation surrounding the top and sides of the tank, a dip tube that directs cold entering water to the bottom of the tank, a hot water outlet pipe, a combustion chamber, a sacrificial anode, a flue within the water tank, a baffle-type heat exchanger within the flue, an oil-fired power burner system, a burner control thermostat, a temperature and pressure-relief valve, an outer case, and packaging for shipment. Manufacturers may differentiate oil-fired water heaters by efficiency rating, input to burners, and storage capacity.

Electric Storage Water Heater. The baseline electric storage water heater is a water heater that incorporates a complete electric powered water heating system in an individual package. Each baseline electric water heater consists of a glass-lined corrosion-resistant steel tank, insulation surrounding the top and sides of the tank, a dip tube that directs cold entering water to the bottom of the tank, a hot water outlet pipe, heat traps, electric resistive heating elements, a control thermostat and wire harness, a sacrificial anode, a temperature and pressure-relief valve, an outer case, and packaging for shipment. Manufacturers may differentiate electric water heaters by efficiency rating, input to the heating elements, and storage capacity.

Instantaneous Gas-Fired Water Heaters. The baseline instantaneous gas-fired water heater is a water heater that incorporates a complete instantaneous gas-fired water heating system in an individual package. Each baseline instantaneous gas-fired water heater consists of a cold water inlet, a hot water outlet, a combustion chamber, a heat exchanger, a burner, a vent, a standing pilot ignition, a flow detection device, a gas valve, a burner control thermostat, an outer case, and packaging for shipment. Manufacturers may differentiate instantaneous gas-fired water heaters by efficiency rating and input to the burners.

3.3.1.2 Baseline Direct Heating Equipment

Gas Wall Fan Type. The gas wall fan-type heater is a heater that incorporates a complete gas heating system in an individual package. Each baseline gas wall fan-type heater consists of a heat exchanger, a room air circulation blower, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue, an intake, a burner control thermostat, an outer case, and packaging for shipment. Manufacturers may differentiate gas wall fan-type heaters by efficiency rating and input rating.

Gas Wall Gravity Type. The gas wall gravity-type heater is a heater that incorporates a complete gas heating system in an individual package. Each baseline gas wall gravity-type heater consists of a heat exchanger, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue, an intake, a burner control thermostat, an outer case, and packaging for shipment. Manufacturers may differentiate gas wall gravity-type heaters by efficiency rating and input rating.

Gas Floor Type. The gas floor-type heater is a heater that incorporates a complete gas heating system in an individual package. Each baseline gas floor-type heater consists of a heat exchanger, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue, an intake, a burner control thermostat, a floor grate, an outer case, and packaging for shipment. Manufacturers may differentiate gas floor-type heaters by efficiency rating and input rating.

Gas Room. The gas room-type heater is a heater that incorporates a complete gas heating system in an individual package. Each baseline gas room-type heater consists of a heat exchanger, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue, an intake, a burner control thermostat, an outer case, and packaging for shipment. Manufacturers may differentiate gas room-type heaters by efficiency rating and input rating. Manufacturers may also differentiate by outer case. Room heaters can be packaged as console and hearth-type heaters.

Gas Hearth. A gas hearth heater simulates a wood-burning device. Each baseline vented gas hearth product consists of a heat exchanger, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue, an intake, a burner control thermostat, ceramic logs, an outer case, and a tempered glass viewing pane. Manufacturers may differentiate vented gas hearth DHE by efficiency rating and input rating.

3.3.1.3 Baseline Pool Heaters

A gas-fired pool heater incorporates a complete pool heating system in an individual package. Each baseline gas pool heater consists of a cold water inlet pipe, a hot water outlet pipe, a heat exchanger, a standing pilot ignition system, a burner, a pilot light sensing control valve, a combustion chamber, a flue/vent, an air intake, a burner control thermostat, an outer case, and packaging for shipment. Manufacturers may differentiate gas-fired pool heaters by efficiency rating or input rating.

3.3.2 Technology Options

3.3.2.1 Water Heaters

DOE identified the following technology options as having the potential to improve the efficiency of water heaters:

1. Heat traps
2. Insulation improvements
3. Power vent (gas-fired and oil-fired only)
4. Heat exchanger improvements
5. Flue damper (electromechanical)
6. Side arm heater
7. Electronic (or interrupted) ignition
8. Heat pump water heater (electric only)
9. CO_2 heat pump water heater
10. Flue damper (buoyancy operated)
11. Directly fired
12. Condensing
13. Condensing pulse combustion
14. Thermophotovoltaic and thermoelectric generators
15. Reduced burner size (slow recovery)
16. Timer control
17. Two-phase thermosiphon (TPTS)
18. Modulating controls
19. Intelligent controls
20. Self-cleaning.

Heat Traps (Oil Fired). Residential water heaters lose heat by conduction and convection through the fittings (water pipes, drain valve, pressure relief valve, and thermostat), which contributes to standby losses. A heat trap is a device or arrangement of piping that keeps the buoyant hot water from circulating to the piping distribution system by natural convection, which leads to heat loss through uninsulated pipes to the surroundings. When there is no draw of hot water, a heat trap prevents water in the hot water outlet line from getting back into the tank as it cools off, and prevents hot water in the tank from circulating back into the cold water inlet line. Thus, by containing hot water in storage tanks, heat traps minimize standby loss. These devices can be integral to tank design or independently attached to inlet and outlet pipes during installation at the site. Insulating its exposed portion can increase the effectiveness of a heat trap. Multiple manufacturers include heat traps on their water heater models.

Conventional heat traps come in two styles. In the first style, a floating plastic ball blocks the cold water inlet. The buoyancy of the plastic holds it in place until water is drawn. The force of water is strong enough to push the ball out of the way as water enters the tank.

The second style is used for the hot water outlet. In this heat trap, the ball is denser than water, and the weight of the ball seals the outlet until hot water is drawn and the water pressure lifts it out of the way. A small bypass channel is left for water to escape back into the inlet line from the tank after a large draw fills the tank with cold water. Heat traps can also be made of metal. Manufacturing costs appear to be roughly comparable between metal and plastic heat traps, but plastic heat traps are considerably more effective in reducing water heater standby losses.

Other heat trap designs include U-shaped pipes, flexible seals, flaps, and springs.

Insulation Improvements (Gas-Fired, Oil-Fired, Electric Storage). Standby losses can be reduced by improving water heater tank insulation. Increasing the thermal resistivity of the water heater jacket to reduce the amount of heat loss during standby periods increases the water heater energy factor.

Insulation can be improved by modifying the baseline design of the standard gas-fired storage water heater using (1) increased jacket insulation, (2) a plastic tank, (3) an insulated tank bottom (electric only), (4) advanced forms of insulation, and (5) foam insulation.

Increased Jacket Insulation. Manufacturers insulate gas-fired, electric, and oil-fired storage water heaters by filling the cavity between the jacket and the tank (top and sides) with insulation. Most storage water heaters on the market today have at least 1-inch thick insulation; some models have 2- or 3-inch thick insulation. Increasing the diameter of the jacket insulation will reduce standby losses by increasing the thermal resistivity of the water heater jacket. Jacket losses represent a majority of the standby losses. Some manufacturers produce water heaters with increased insulation. After-market insulating blankets are also commercially available to increase water heater insulation.

Plastic Tank (electric only). Plastic water heater storage tanks can be constructed using a seamless, blow-molded polybutylene inner tank with a filament-wound fiberglass outer tank. A second method involves constructing a thin steel shell with an internal plastic tank. The steel exterior is constructed first, then plastic powder is injected into the shell and the tank is rotated in a furnace to coat the interior with the plastic. The steel exterior serves as the primary structural support for the tank. The lower heat conductivity of plastic compared to metal reduces the amount of heat conducted through the tank wall to the insulation and to the feed-throughs. However, the plastic tank cannot be used with standard center-flue gas-fired storage water heaters or with oil-fired storage water heaters because the plastic cannot withstand the high temperatures produced by the flames.

Insulated Tank Bottom (electric only). Insulated tank bottoms increase water heater efficiency by reducing standby losses. The standard water heater tank is not insulated on the bottom, where water temperature is lowest. However, the tank bottom is still conductive; therefore, adding insulation will reduce heat dissipation through the bottom of the tank.

Advanced Forms of Insulation. Alternate ways of reducing the jacket losses without increasing the diameter of gas-fired, electric, and oil-fired storage water heaters include using advanced insulation materials or evacuated panels. Some of the advanced materials or methods of insulation considered here involve using vacuum insulation, inert gases, aerogel insulation, or partial vacuums.

Vacuum Insulation. A "hard" vacuum between internal reflective surfaces is a very good insulator. It has been used for years in Thermos bottles and Dewar tanks for cryogenic applications. Durability and the difficulty of maintaining the seal over the life of the storage water heater are some manufacturing problems that have to be resolved.

Gas-Filled Panels. Gas-filled panels are thermal insulating devices that retain a high concentration of a low-conductivity gas at atmospheric pressure within a multilayer infrared reflective baffle. The thermal performance of the panels depends on the type of gas fill and the baffle configuration. Gas-filled panels are flexible and self-supporting, and can be made in a variety of shapes and sizes to thoroughly fill most types of cavities. This technology has not been demonstrated for water heater applications.[47]

Aerogel Insulation. An example of advanced insulation materials is silica aerogel, which is composed of 96 percent air and 4 percent silicon dioxide. Aerogels are more efficient and weigh less than the polyurethane foam currently used in most water heaters. The R-value of the aerogel at atmospheric pressure is comparable to that of the polyurethane foam, but when 90 percent of the air is evacuated from a plastic-sealed aerogel packet, its resistance nearly triples. Another advantage of aerogel insulation over foam insulation is avoiding the use of chlorofluorocarbons to blow the polyurethane foam into the heater jacket. New manufacturing processes have been developed that can produce flexible blankets or clamshell forms of this material. The aerogel material is vulnerable to shock and vibration, however, and material handling is an issue. Because the aerogel is hygroscopic, it requires a thorough sealing of the cavity between the water heater tank and the outside cover. The material has not been demonstrated for use with water heaters.

Evacuated Panels. Other materials with a lightweight open structure can provide effective insulation combined with "soft" or low vacuums. The materials can be enclosed with metals or plastic. A vacuum is drawn in this panel before sealing, and a lightweight, rigid foam keeps the vacuum from compressing the panel. This technology has not been demonstrated for storage water heater applications.

Foam Insulation. Foam insulation can be used as an alternative to fiberglass insulation. Chlorofluorocarbon-free, water-blown polyurethane foam is a common alternative to high-density fiberglass blankets. Incorporating foam insulation of the same thickness in place of fiberglass insulation can increase overall efficiency of the storage-type water heater. Foam typically has an R-value up to two to three times greater than fiberglass. Additionally, foam can be blown into the cavity between the tank and the outer case and does not need to be cut to form as required by some fiberglass installation methods. This facilitates the filling of small spaces and constrictive geometries where the potential for heat loss still exists, and which would be difficult to fill with fiberglass batts. Finally, manufacturing processes that use foam-blowing techniques are better suited for production line changes due to the shape-conforming characteristics of the foam. This allows additional technology options, methods, and advances to be incorporated into current designs with minimal impacts on insulation installation techniques.

Power Vent (Gas-Fired and Oil-Fired Storage). The power vent technology option can increase the recovery efficiency, depending on the specific set-up of the technology. Power vents can be designed as either induced or forced draft systems. An induced draft fan is installed downstream of the draft diverter in the venting system and pulls flue gases through the flue. A forced draft fan is upstream of the combustion chamber and supplies the correct fuel-to-air ratio for combustion. Both methods improve efficiency by increasing turbulence in the flue gases.

Typically, this technology is incorporated with a flue baffle that has a more restricted flow path. Induced and forced draft fans can transmit air through the restricted flue baffle, where a natural venting system would not be possible. This restriction of air flow increases mixing, which increases heat transfer, thermal efficiency, and recovery efficiency. When recovery efficiencies reach above 80 percent, condensation of flue gases is likely. Water heaters obtaining recovery efficiencies above 80 percent should include methods to properly dispose of condensate and be made of materials that resist corrosion caused by condensate.

In addition to an increase in efficiency, there is also a reduction in standby loss. The restrictions created by the stationary blower installed in either the intake or flue paths reduce the off-cycle standby loss. The blowers act like dampers.

Some manufacturers make water heaters with induced draft fans that, in addition to pulling the combustion products through the water heater, also draw excess air into the flue gases before venting. This is similar to a vent hood used in natural venting applications. Adding ambient air cools flue gases leaving the water heater to a low enough temperature so that standard plastic piping can be used for venting. This eliminates any problems with metal vent pipe corrosion. Plastic piping is often cheaper and easier to install than sheet metal or masonry chimneys.

Heat Exchanger Improvements (Gas-Fired, Oil-Fired Storage, and Instantaneous). Heat transfer from the flue gases to the water can be enhanced by improving the flue baffle or heat exchanger. The improved heat transfer leads to an increase in the thermal efficiency of the water heater. If the thermal efficiency is increased to about 84 percent, condensation of the flue gases begins to occur in the flue or vent pipe. Condensation may cause the surfaces of the flue and vent pipe to corrode. To avoid such problems, materials that resist corrosion and methods to properly collect and dispose of condensate are incorporated into water heater designs.

The heat exchanger can be improved by modifying the baseline gas-fired storage water heater using (1) increased heat exchanger surface area, (2) an improved flue baffle, (3) a submerged combustion chamber, (4) multiple flues, (5) alternative flue geometry (helical), or (6) a u-tube flue. These approaches can increase recovery efficiency significantly, but may also cause condensation (and hence corrosion) to occur in venting systems.

Increased Heat Exchanger Surface Area. The baseline design consists of a vertical flue in the center of the gas-fired or oil-fired storage water heater tank. This design can be improved by increasing the surface area of the flue, which increases the amount of heat transfer and thermal efficiency. One way to accomplish this is by increasing the diameter of the flue. The overall tank diameter would need to be increased to maintain consistent volume. Tank height could also be increased to maintain the same volume, which would also add surface area to the flue. The flue baffle would most likely require modification in order to maintain the same amount of air flow restriction.

Enhanced Flue Baffle. The standard flue baffle of a gas-fired and oil-fired storage water heater is a twisted strip of metal inserted into the flue that increases the turbulence of flue gases and improves heat transfer to the walls of the flue. The geometry of the flue baffle can be modified to increase its effectiveness. Improving the flue baffle so that air flow becomes more restricted and more turbulent can increase the amount of heat transfer, which increases the thermal efficiency. Increasing the length of the path that the flue gases travel and including more turns in the flue gas path can improve the flue baffling. This can be accomplished by including fins or some other form of extrusion from the flue wall, or by increasing the number of flow altering features in the baffle, which is typically constructed from a flat piece of sheet metal and inserted into the flue. These methods to enhance the flue baffle, which increase air flow restriction and turbulence, may also result in an increased surface area, which also increases heat transfer. Enhanced flue baffle technology can also reduce standby losses. Enhancements to the flue baffle typically create restrictions to the air flow, which decreases convective heat loss during standby periods.

Submerged Combustion Chamber. The combustion chamber in a standard gas-fired and oil-fired storage water heater is below the water tank, and the bottom of the tank (below the burners) is seldom insulated. Therefore, the water heater loses heat from below the tank. The sides and bottom of the combustion chamber are not surrounded by water. By inserting the combustion chamber into the storage tank, more of the combustion energy can be recovered. Standby losses are reduced somewhat because of restrictions on air flow through the combustion chamber and flue.

Multiple Flues. The multiple flue design uses several smaller flues in place of one large central flue in the middle of the storage tank. The increased surface area for heat exchange between the flue gases and the water in the tank yields an increase in recovery efficiency.

Alternative Flue Geometry (Helical). This technology option is most often associated with condensing gas-fired storage water heaters, but it also applies to oil-fired storage water heaters. The technology incorporates both a helical or spiraling flue and a u-tube flue. This technology contributes to increased efficiency in two distinct ways. The surface area of the flue is increased, since it runs a helical path considerably longer than the height of the water tank, increasing heat transfer during steady-state operations. Also, when the burner is not operating, the multiple turns in the flue resist heat convection out of the flue, reducing standby losses. Directing the flue downward with a "U" shape allows the forming condensate to drain from the water heater flue properly. The flue usually exits the sidewall of the water heater. Safety concerns exist due to the corrosive and acidic nature of the flue gas condensate; corrosion-resistant materials are used to mitigate this damage.

U-Tube. A u-tube flue for a gas-fired or oil-fired storage water heater is a flue shaped like an inverted "U" within the water heater tank. This shape contributes to increased efficiency in two distinct ways. The surface area of the flue is increased, as it runs twice the height of the water tank, increasing heat transfer during steady-state operation. This effect is similar to the increased heat exchanger surface area technology option. When the burner is not operating, the inverted u-shaped flue resists heat convection out of the flue, reducing standby losses. This effect is similar to the flue damper technology options.

Direct Vent. Another method to increase surface area includes a secondary heat exchanger. Combustion gases exiting through the vent preheat incoming air before it passes through the primary heat exchanger. Manufacturers currently produce instantaneous water heaters that accomplish this by running the inlet and exhaust vents concentrically. This venting configuration is known as direct-vent. This set-up is similar to a shell-in-tube heat exchanger.

Manufacturers currently produce water heaters with heat exchanger improvement technologies.

Electromechanical Flue Damper (Gas-Fired Storage). Gas-fired storage water heaters are typically equipped with a draft hood connecting the flue pipes to a vent pipe or chimney. During off-cycle, the water heater loses heat by natural convection and conduction through the vent pipe or chimney. Installing a damper at the flue exit or in the vent pipe can minimize the off-cycle heat losses. A flue damper is installed upstream of the draft diverter, while the vent damper is installed downstream of the draft diverter.

Electric flue dampers are activated by an external source of electricity. The dampers open when combustion starts and close immediately after combustion stops. Therefore, there is a greater reduction in off-cycle losses compared to buoyancy-activated dampers. When the damper reaches the open position, an interlock switch energizes the solenoid and enables the gas ignition circuit. Therefore, the burner cannot be ignited when the damper is in the closed position. Because the dampers open and close immediately, no bypass is needed. However, a knockout vents the flue gases from a standing pilot. The electric flue damper needs an electric hookup and consumes power when the gas supply is off.

Flue and vent dampers have no effect on the steady-state performance of the water heater. However, flue and vent dampers can reduce standby losses of gas-fired storage water heaters, yielding improved energy efficiency. Some commercial water heaters use flue dampers.

Side Arm Heater (Gas-Fired, Oil-Fired Storage). The side arm heater technology option for gas-fired and oil-fired storage water heaters avoids large flue losses by removing the flue from the center of the storage tank. Water is withdrawn from the bottom of the tank, heated over a burner in a small, separate heat exchanger, and returned to the top of the tank. A small circulation pump moves water through the heat exchanger when the burner is on. The burner could have electronic ignition, which would reduce pilot light losses. A low-voltage transformer, fed by a standard 120-volt wall connection, supplies auxiliary power. Water heaters using this design are not currently on the market.

Electronic (or Interrupted) Ignition (Gas-Fired, Oil-Fired Storage, and Instantaneous). The most commonly used ignition system in gas-fired and oil-fired storage water heaters and instantaneous water heaters is a standing pilot ignition system. The disadvantage of these water heaters is that they burn gas continuously at a rate of about 1000 Btu/hr, and only part of this heat is converted to useful energy. As an alternative to standing pilots, three electronic ignition devices are sometimes used in gas-fired and oil-fired storage water heater and instantaneous water heater products:

Intermittent Pilot Ignition. This is a device that lights a pilot by generating a spark, which in turn lights the main burner.

Intermittent Direct Ignition. This system lights the main burner directly by generating a spark.

Hot Surface Ignition. This system lights the main burner directly via a sufficiently hot surface.

Hydroelectric ignition is another form of electronic ignition used in gas-fired products, particularly instantaneous water heaters. However, it is not as common as the three forms of ignitions above. For hydroelectric systems, a small turbine is spun by flowing water to produce electricity, which ignites a pilot. This is similar to intermittent pilot ignition.

Unlike standing pilot ignition systems that consume gas continuously, hydroelectric devices operate only at the beginning of each on-period. Although there is no increase in the steady-state efficiency with the use of electronic ignition devices, they reduce overall fuel consumption. Burner on-time may increase, however, to make up for the heat the standing pilot would have supplied during standby periods.

The "interrupted ignition" system for an oil-fired burner activates the spark only until a steady flame is established. This differs from "intermittent ignition" for oil-fired burners, where the energy source is activated during the entire burner operating cycle. Interrupted ignition does not affect oil consumption, and there is no improvement in the recovery efficiency of the water heater. However, this technology option not only reduces the igniter's electricity consumption, but also reduces its maintenance costs because the electrodes do not have to be replaced as often. In addition to changes in controls, the igniter can be made from solid-state electronics, instead of an iron core transformer. This improves performance and also reduces power consumption. Manufacturers produce water heaters with electronic ignition.

Heat Pump Water Heater (Electric Storage). A heat pump water heater represents a merging of two otherwise unrelated technologies: an electric resistance storage water heater with tank and controls, and a refrigeration circuit similar to that found in a residential air-conditioner. Heat pump water heaters use existing heat pump technology to extract heat from the surroundings for heating stored water. For electric water heaters, this is an alternative to resistive heating. Heat pump water heaters transfer heat from air, typically at room temperature, to water at a higher temperature. The heated water can then be used to provide the residential hot water supply. Since heat does not naturally transfer from a low temperature to a higher temperature, a mechanical system consisting primarily of a closed refrigeration loop containing a refrigerant vapor compressor, an evaporator (a type of heat exchanger), a condenser (another heat exchanger), and an expansion device is used to transfer the heat. The working fluid in the loop, the refrigerant, extracts heat from the surrounding air. Typically, the evaporator captures heat from the ambient air, and the condenser delivers this heat to the water inside of a storage tank. The pump and expansion device facilitate pressure and phase changes to allow for these heat transfer processes.

When used continuously, typical heat pumps appear to heat water at roughly two and a half to three times the rate of energy input (in the form of electricity). In practice, actual tested residential heat pump water heater designs typically yield energy factors from approximately 1.0 to 3.0,[48] while a baseline electric storage water heater has an energy factor of 0.90. An energy factor range exists because of variations in design and ambient conditions. For example, differences in piping between the heat pump and storage tank, efficiencies of the individual components of the heat pump loop, and storage tank characteristics affect EF.

It should be noted that most U.S. homes are heated for substantial portions of the year, and operating a heat pump water heater typically extracts heat from the household air and increases the load on the home heating system during these periods. Energy factors for heat pump water heaters, or any water heaters, do not consider home heating loads. For this reason, accounting for the net energy or energy cost impact of the heat pump water heater requires analyzing the energy cost impact on the entire house, not just the electrical energy input to the water heater.

There are two basic designs for residential heat pump water heaters: add-on and integral. An add-on heat pump water heater is designed to be added to a separately manufactured storage tank, often a standard electric resistance water heater. A small pump circulates water from the tank through the heat pump. The heat pump and storage tank are combined in the field during installation. The second type of heat pump water heater is an integral heat pump water heater. In an integral design, the heat exchanger (condenser) is combined with the storage tank design during the manufacturing process. This eliminates the need for a circulation pump and increases efficiency. Both heat pump configurations typically supplement resistive, or traditional electric, storage water heaters where the elements operate only when the demand for hot water is greater than what the heat pump can supply.

Both designs have a refrigeration subsystem composed of at least an expansion device, evaporator, compressor, and a fan (to force air over the evaporator and enhance heat transfer). The refrigerant condenser, also part of the refrigeration loop, can be located with the rest of the subsystem as a separate unit (as is done with the add-on-type heat pump water heater), or be integral to the tank as with the integral heat pump water heater design. In the add-on heat pump water heater, cold water is removed from the tank, heated, and pumped back into the tank. In the integral design, the heat pump compressor moves refrigerant from the condenser coil to the evaporator coil. The condenser coil is typically either inside the tank or wrapped around the tanks exterior (*i.e.*, between the tank wall and the insulation). The evaporator coil is typically housed on top of the tank along with the remaining heat pump components. The compressor, evaporator coil, and evaporator fan mounted on top of the storage tank will add approximately 12 inches to the height of a traditional electric water heater tank. Regardless of design, the expansion device, evaporator, fan, and compressor must be located outside the tank. In the add-on design, components can be mounted on top of the tank or as a completely separate unit that can be placed on the floor or mounted on the wall. For higher efficiencies, the add-on heat pump water heater should be placed relatively close to the tank. As the unit is placed farther from the tank, the water heating efficiency degrades due to piping losses, predominantly the result of warm water left in the piping between on-cycles that results in heat transfer to the surroundings.

The heat pump water heater also produces condensate at the evaporator coil during operation. Like all refrigeration devices, the evaporator coil must be cold to extract heat from the surrounding air. When air blows across the coil, moisture in the air is condensed to liquid. The amount of liquid produced is a function of the humidity in the air blown across the coil, the temperature of the evaporator coil, and the hot water load. Locating the heat pump in the conditioned space of a residence does not eliminate all the condensate buildup unless the air conditioning system can be counted on to dehumidify all house air to a dew point below the coil temperature. Therefore, condensate drains are typically required to remove condensation that collects as a result of operation. A pump may also be needed to move condensate to a drain.

Most residential heat pump water heater designs need back-up electric resistance heating elements because cost and space considerations limit the heating capacity of the refrigeration system. Typical heat pump water heaters have between 40 and 80 percent of the heating capacity of typical electric resistance storage water heaters. To compensate for this reduced heating capacity and allow faster water heating and shorter recovery periods for the heat pump water heater during periods of high use, electric resistance heaters are employed that can heat the water in the tank faster than the heat pump unit. The cost of larger capacity systems generally outweighs the energy efficiency benefits to the average consumer. Additionally, removing large amounts of heat from a conditioned space during high use periods with a larger system may create unfavorable conditions in a residence. Instead, practical systems are designed to heat water gradually using the higher efficiency heat pump, but can, when required by the heating load, use a higher capacity electric resistance backup.

Finally, the space in which the heat pump water heater is located must be large to provide adequate air flow and must provide ready access for regular air filter changes on the heat pump evaporator coil. The refrigeration subsystem of a heat pump water heater needs sufficient flow of warm air across the evaporator coils to serve as a heat source. Without this heat source, the heat pump cannot function and must revert to electric resistance operation. Operation in heat pump mode will generally require about 100 cubic feet per minute or more of warm air. Multiple manufacturers produce heat pump water heaters. Multiple manufacturers produce heat pump water heaters, conduct heat pump research, and develop prototype designs.

Carbon Dioxide (CO_2) Heat Pump Water Heater (Electric Storage). CO_2 heat pump water heaters are similar to the aforementioned heat pump water heater technology. This technology uses carbon dioxide as a natural refrigerant to transfer heat from the surrounding air to the water stored in the tank through a heat pump loop. Current products and prototypes can achieve coefficients of performance as high as 3.0,[49] which result in EFs ranging from approximately 1.0 to 3.0. This range accounts for differences in ambient air conditions, storage tank efficiency, and efficiencies of the components that make up the heat pump loop. Additionally, some products installed outdoors can function in cold weather without freezing pipes or frosting evaporators. Typically, this technology is installed outdoors due to the size of components. Typical installations include a separately packaged heat pump and a separately packaged storage unit consisting of two tanks and supporting hardware. CO_2 heat pump water heaters also take advantage of load shifting strategies by heating water at night and storing it for use during the day. Products are predominantly available outside of U.S. markets where products have been made available by government subsidy rebate programs.[50]

Buoyancy Operated Flue Damper (Gas-Fired Storage). This flue damper is a small, very lightweight aluminum dome-shaped poppet that slides up and down in an enclosure placed at the top of the flue of a gas-fired water heater. The buoyancy of the combustion products lifts the poppet, allowing flue gases to enter the venting system.

This technology option would reduce off-cycle standby losses by sealing the flue and preventing convection to the venting system, but would have no effect on recovery efficiency because it does not affect the rate of heat transfer. This flue damper may not work with high recovery efficiency water heaters because there may not be enough waste heat in the combustion products to provide sufficient buoyancy to lift the poppet.

The safety standard[51] for gas water heaters requires the burner to shut off if the flue gets blocked for some reason. Thus, the effects of a failure of the flue damper to open should be mitigated by the burner controls.

Directly Fired (Gas-Fired, Oil-Fired Storage). In this technology option, water is sprayed through a series of baffles above the burner of gas-fired and oil-fired storage water heaters. Burner flame and flue products are in direct contact with the water, which is re-pressurized by a circulating pump and returned to the storage tank. The direct contact process allows for more efficient heat transfer than conventional shell-and-tube gas-fired and oil-fired storage water heaters because the heat resistive barrier between the water and the flue products is eliminated. However, direct contact with flue products can lead to contamination of the domestic water. This can potentially cause health and safety problems for end users. This technology option can also cause conflict with local and uniform plumbing codes (*e.g.*, International Association of Plumbing and Mechanical Officials (IAPMO) 1991) with respect to water quality.

Condensing (Gas-Fired, Oil-Fired Storage, and Instantaneous). Energy efficiency of gas-fired and oil-fired storage and instantaneous water heaters can be increased by extracting more heat from the flue gases. More energy can be extracted by condensing the combustion products in the flue gas, which extracts more heat in the form of latent energy, leading to an increase in the thermal efficiency of the gas-fired and oil-fired storage and instantaneous water heater. Water heater technology options or a combination of technology options can be added to a water heater design to condense the combustion gases.

The flue-gas condensate is often acidic and corrosive. Therefore, special corrosion-resistant heat exchangers and vent linings are required for safe and reliable operation of the water heater. Corrosion due to condensation of combustion gases limits the thermal efficiency of a fuel-fired water heater with a standard flue and vent system. Using corrosion-resistant heat exchangers or sidewall venting, and lining the vent/masonry systems with corrosion-resistant material can extend the thermal efficiency.

Condensing gas appliances can be fully condensing or near condensing. Fully condensing appliances have flue gas temperatures less than the dew point (130 ºF to 140 ºF) of the flue products. Condensation is expected in both the heat exchanger and the vent system. Near-condensing appliances have flue gas temperatures approaching the dew point of the flue gases, but still greater than the dew point. Condensation is expected in the vent system but not in the heat exchangers. The thermal efficiency of fully condensing water heaters can be as high as 99 percent. For near-condensing water heaters, thermal efficiency is generally between 84 and 90 percent. Manufacturers produce residential and commercial condensing water heaters.

Condensing Pulse Combustion (Gas-Fired, Oil-Fired Storage, and Instantaneous). Pulse combustion burners for gas-fired and oil-fired storage and instantaneous water heaters are another condensing technology. Pulse combustion burners operate on self-sustaining resonating pressure waves that alternately rarefy the combustion chamber (drawing a fresh fuel/air mixture into the chamber) and pressurize it (causing ignition by compression heating of the mixture to its flash point). This process is initiated by a blower supplying an initial fuel and air mixture to the combustion chamber. A spark ignites the mixture. Once resonance is initiated, the process becomes self-sustaining.

Pulse combustion systems feature high heat transfer rates, can self-vent, and can draw outside air for combustion even when installed inside. Because the pulse combustion process is highly efficient, the burners are generally used with condensing appliances.

Thermophotovoltaic and Thermoelectric Generators (Gas-Fired, Oil-Fired Storage, and Instantaneous). Heat and light energy can be extracted from the combustion process of gas-fired and oil-fired storage and instantaneous water heaters and converted into useful electrical energy. Thermophotovoltaic generator technology uses a special light-emitting burner coupled with silicon photovoltaic cells that generate auxiliary power that can run a fan, operate the electronic ignition and controls, and charge a battery. This avoids the requirement of an auxiliary electrical supply, while offering the efficiency advantages of electronic ignition and forced-draft combustion.

Another method of generating electricity at the water heater is based on thermoelectric technology. Thermoelectric generators use semiconductors to convert a temperature differential into a voltage source. This voltage source can provide power to run a fan, operate the electronic ignition and controls, and charge a battery, similar to the thermophotovoltaic generator. Thermoelectric generators are available, but none have been used to generate auxiliary power for water heaters.

Reduced Burner Size (Slow Recovery) (Gas-Fired, Oil-Fired Storage, and Instantaneous). Reducing burner size for gas-fired and oil-fired storage and instantaneous water heaters while keeping flue baffle and tank geometry the same will increase the ratio of heat transfer surface area to energy input, thereby increasing the recovery efficiency. The lower energy input means that recovery would be slower than with conventional burners.

Timer Control (Electric Storage). This technology option limits the time of day when the elements of an electric storage water heater may be energized. This is most often used as part of an electric utility demand-side management program for load shifting ("demand avoidance strategy"). Energy savings are possible because the water in the tank remains at a reduced temperature for part of the day. However, the actual energy savings will depend on the end-use profile, lifestyle of the consumer, and a basic desire to save energy. Savings will be greater for water heaters where standby loss levels are high because the electric consumption, in response to the standby losses, shifts from on-peak to off-peak times when electricity costs less.

After-market timer controls for water heaters are commercially available. Some utilities also offer load-shifting controls for water heaters to reduce peak daytime demand.

Two-Phase Thermosiphon (Gas-Fired, Oil-Fired Storage). Two-phase thermosiphon (TPTS) technology removes the flue from the center of gas-fired and oil-fired storage water heaters and places a heat exchanger outside the storage tank, reducing standby losses. This is similar to the side-arm heater technology option. TPTSs are heat-pipe mechanisms that transfer heat from the external burner to the storage tank. The TPTS is a closed loop device consisting of an evaporator, in which the working fluid (water) is heated by the burner, percolating liquid and vapor into the condenser where heat is transferred into the water storage tank. At the condenser, which is inside the storage tank, the vaporized working fluid is condensed and drains back through a separate restricted tube to the evaporator, where it is reheated. The restriction prevents the heated vapor and liquid from flowing to the condenser through the return path. During off-cycle, there is very little heat transfer through the TPTS system. This reduces standby losses to levels similar to those of electric water heaters.

Modulating Controls (Instantaneous). Modulating controls within an instantaneous water heater can reduce energy consumption, improve efficiency, and improve overall performance by changing the operating conditions in response to household demand. Basic controls (*i.e.*, those without modulation) operate at either the minimum or the maximum output levels, based on simple inputs from either the user or the water heater. Alternatively, modulating controls can reduce output so that excess energy is not wasted when only small temperature differentials or low flow rates need to be satisfied. By modulating the controls, the demand can be met more precisely by the appropriate outputs. For example, a control will not open fully to correct a small differential; rather, the control will modulate to a lower, or stepped, position to avoid wasting energy. An added benefit to modulation is the elimination of stacking, the effect of overheating due to a succession of short hot water draws. Stacking can lead to scalding and other safety issues. Finally, duty cycling can be reduced, which can reduce the total amount of energy consumed. Several manufacturers currently include modulating controls in instantaneous water heaters.

Intelligent Controls (Gas-Fired, Oil-Fired, Electric Storage, and Instantaneous). Intelligent controls, self diagnostics, and electronic controls for storage and instantaneous water heaters minimize energy consumption and maximize hot water output. Monitoring functions typically operate to minimize operating cost while still meeting household demand. This works by tracking usage patterns and adjusting water heater operations to maximize efficiency. Also, water heaters may employ economizer modes to limit the maximum temperature to reduce energy consumption. Smart vacation settings operate to minimize energy usage while maintaining temperatures above freezing. Diagnostic software may also maintain the optimal burner conditions, valve positions, and air-to-fuel ratios to maximize efficiency, for example. Several storage- and instantaneous-type water heaters incorporate intelligent, self-diagnostic, and electronic controls.

Self-Cleaning (Gas-Fired, Oil-Fired, Electric Storage). This technology option for storage water heaters is a modification of the conventional dip tube associated with the baseline storage water heater. Water exits a conventional dip tube with a weak diffusing action. Self-cleaning technology incorporates a method to introduce the inlet water at high turbulence. This is accomplished by modifying the exit orifice at the end of the dip tube to increase the inlet velocity of the water and create a spray pattern. Designs may also incorporate orifices along the length of the dip tube. These introduce inlet water at various points within the tank to increase mixing and overall tank turbulence. Further designs may turn the flow path of the inlet water to a horizontal angle to increase the amount of swirling, or rotational turbulence. This can be accomplished by simply bending the dip tube.

This technology has the benefit of self-cleaning, but this does not contribute to an increase in energy efficiency as measured by the DOE test procedure. By introducing the inlet water at higher velocities and with turbulence, naturally occurring sediment in the water is forced to remain in suspension. Therefore, the sediment can be drawn out of the tank when there is a call for hot water, instead of settling to the bottom. If long standby periods occur, the dip tube is designed to unseat any settled particles so that they can be withdrawn from the tank. This prevents the formation of permanent deposits, which degrade heat transfer. Deposits decrease water heater performance, can cause leaks, and reduce tank volume.

3.3.2.2 Direct Heating Equipment

DOE identified the following technology options that might improve the efficiency of direct heating equipment:

1. Heat exchanger improvements
2. Electronic ignition
3. Thermal vent damper
4. Electrical vent damper
5. Power burner
6. Induced draft
7. Two stage and modulating operation
8. Improved fan or blower motor efficiency
9. Increased insulation (floor furnaces only)
10. Condensing
11. Condensing pulse combustion
12. Air circulation fan
13. Sealed combustion

Heat Exchanger Improvements (Fan Wall, Gravity Wall, Floor, Room, Hearth). Improving the heat exchanger for fan wall, gravity wall, floor, room, and hearth heaters can improve heat transfer from combustion gases to the air. The improved heat transfer leads to an increase in the thermal efficiency and AFUE of direct heating equipment. If the AFUE increases to about 90 percent, condensation of the combustion gases begins to occur in the heat exchanger or vent pipe. Condensation typically occurs when the combustion gases are cooled to approximately 130 ºF. Condensation may cause corrosion to the surfaces of the heat exchanger and vent pipe. To avoid such problems, direct heating equipment designs incorporate materials that resist corrosion and methods to properly collect and dispose of condensate. If the design does not include a means to manage condensate, the use of this technology option will be limited to an AFUE below 90 percent to avoid damage.

The technology option of improved heat exchanger can be achieved by modifying baseline designs of standard gas-fired direct heating equipment using (1) increased heat exchanger surface area, (2) multiple flues, (3) multiple turns in flue, (4) direct vent, and (5) increased heat transfer coefficient.

Increased Heat Exchanger Surface Area. The performance of the heat exchanger can be improved by simply increasing its surface area, which increases the amount of heat transfer occurring in the direct heating equipment. This, in turn, improves the direct heating equipments' ability to extract heat from combustion gases. The result is an increase in the steady-state efficiency of the unit, and thus, the AFUE.

Multiple Flues. Incorporating a multiple flue design can increase heat exchanger surface area. The heat exchanger heats room air by passing it through multiple tubes instead of a single tube. One manufacturer incorporates 15 tubes to increase the surface area and increase the rate of heat transfer.

Multiple Turns in Flue. This technology increases heat exchanger surface area by including multiple turns in the flue pipe. Overall dimensions of the outer case do not necessarily need to increase to accommodate a longer flue path. The longer flue path increases heat exchanger surface area, which increases steady-state efficiency and AFUE of the unit. One manufacturer incorporates turns in a heat exchanger to increase surface area and AFUE.

Direct Vent. Another method to increase surface area includes a secondary heat exchanger. Combustion gases exiting through the vent are used to preheat incoming air before it passes through the primary heat exchanger. Manufacturers currently produce direct heating equipment that accomplishes this by running the inlet and exhaust vents concentrically. These units are known as direct-vent heaters. This set up is similar to a shell-in-tube heat exchanger.

Increased Heat Transfer Coefficient. An alternative to increasing the size of the heat exchanger is enhancing the inside and outside heat transfer coefficients of the heat exchanger. This can be accomplished by modifying the surface of the heat exchanger material for the purpose of increasing turbulence in the air passing close to the exchanger's surface, for example. Incorporating dimples or some other surface feature to enhance turbulence can increase the heat transfer coefficient when correctly designed. Also, the heat exchanger may be constructed of a material with a higher thermal conductivity than the standard copper that is typically used.

Electronic Ignition (Fan Wall, Gravity Wall, Floor, Room, Hearth). All gravity-type heaters and the majority of fan-type heaters have a standing pilot ignition system. In direct heating equipment, standing pilots continuously burn gas. The efficiency of the fan wall, gravity wall, floor, room, and hearth heaters can be improved by simply replacing the standing pilot ignition system with an electronic one, such as an intermittent pilot system or a hot surface ignition system. This eliminates the need for the standing pilot.

In assessing the impact on energy consumption, it is important to account for the added electrical energy consumption of the electronic ignition device in addition to the reduction in gas energy consumption that results from eliminating the standing pilot.

The two standing pilot ignition systems for gravity heaters, hydraulic and millivolt, do not require an outside source of electricity to operate. Consequently, these gas valves are more complex and more costly than those of an ignition system requiring a separate power source. For both the hydraulic and millivolt systems, the small amount of electricity that is required by the gas valve and thermostat is generated by either a thermocouple or thermopile. The thermocouple or thermopile draws its power from the burning pilot, and only a small fraction of the heat energy is converted to electricity. The pilot burns at approximately 775 Btu/hr constantly, and the electrical power typically required is only around 1 Watt, or 3.5 Btu/hr. The remaining heat is lost or transferred to the room (even when there is no call for heating).

For fan wall furnaces that already require an outside source of electricity to operate the fan, the electronic ignition system is powered off the fan power supply. The power draw of the fan power supply transformer occurs continuously. For direct heating equipment that does not already require electricity, a means to supply power must be included in the design.

Both hot surface and intermittent pilot electronic ignitions require an outside source of electricity to operate. The gas valve for each electronic ignition system typically only consumes power during a call for heat. The control module, which houses the electronic circuitry required to control the entire ignition system, typically only consumes power during a call for heat. Finally, the electronic thermostat draws power continuously (regardless of whether heat is needed). These power requirements in total are typically less than the pilot burn rate. Manufacturers currently produce direct heating equipment with electronic ignition.

Thermal Vent Damper (Fan Wall, Gravity Wall, Floor, Room, Hearth). Vent dampers are installed between the draft hood and the vent pipe of fan wall, gravity wall, floor, or room heaters. Vent dampers improve efficiency primarily by reducing off-cycle infiltration and off-cycle sensible heat losses. Vent dampers have no effect on steady-state efficiency because they do not improve heat transfer.

A pair of bi-metal coil springs activate thermal vent dampers. Heat created by combustion gases causes the two coil springs to contract and open the damper blade. After heating discontinues, the springs cool and expand, closing the damper. Response time to open and close the damper varies and may be slow because the bi-metal coil spring does not heat up or cool down instantaneously. Thermal vent dampers can be installed on units using either a standing pilot or an electronic ignition system. In the closed position, thermal vent dampers allow some bypass to ensure that combustion gases will not be trapped within the heat exchanger during start up. The bypass also allows the venting of flue gases from a standing pilot. Adding a bypass reduces off-cycle losses because the damper is only partially closed.

Combustion products must maintain a certain amount of heat in order to expand the bi-metal coil springs of the thermal vent damper. If a high efficiency heater transfers nearly all heat to a room and an insufficient amount of heat remains in the combustion gases on contact with the thermal vent damper, there will not be enough heat to open the damper.

Electrical Vent Damper (Fan Wall, Gravity Wall, Floor, Room, Hearth). In direct heating equipment, vent dampers are installed between the draft hood and the vent pipe of fan wall, gravity wall, floor, room, and hearth heaters. Vent dampers improve efficiency primarily by reducing off-cycle infiltration and off-cycle sensible heat losses. Vent dampers have no effect on steady-state efficiency. Vent dampers have no affect on steady-state efficiency because they do not improve heat transfer.

An external source of electricity is needed for electrical vent damper operation. Sensors indicate when the burner is off, allowing for fast closure of the damper. This results in a greater reduction in off-cycle losses than can be achieved with thermally activated vent dampers. Electric vent dampers include safety interlocks to prevent burner operation when the damper is not fully open. Unlike thermal dampers, electric dampers do not allow for bypass since they can open immediately upon burner operation, unless standing pilot ignition is employed. When standing pilots are in use, a knockout on the damper allows standing pilot combustion gases to vent when the damper is fully closed.

Safety concerns do exist. A power failure may cause the electrical damper to remain closed and not cycle open while the heater operates to meet heating demands. This issue is mitigated by including safety interlocks that allow operation of the burner only when the damper is in the open position. Also, a spring return actuator that fails in the open position can be used. In this case, when the electric vent damper experiences a power loss, a spring forces the damper to the open position.

Electrical dampers require an electrical connection, but use only a nominal amount of power during opening and closing. Spring return dampers, if installed, require only a nominal amount of power as well. Power is required while opening and holding closed during standby periods (to overcome the return spring).

Power Burner (Fan Wall, Gravity Wall, Floor, Room, Hearth). Fan-assisted combustion systems for fan wall, gravity wall, floor, room, and hearth heaters can be designed with power burner technology. Power burners use blowers upstream of the combustion zone to supply a more efficient fuel-air mixture to the burner. Power burners also reduce off-cycle losses by restricting air flow and convection of warm air to the vent system, similar to a vent or combustion box damper.

Increasing the amount of primary air to the burner will also increase the accompanying steady-state efficiency. This is accomplished without further design modifications to the heater. Because the power burner can be designed to overcome relatively large pressure drops within the heat exchanger, further increases in steady-state efficiency can be attained by redesigning the heat exchanger system. The heat exchanger can be designed to be more compact with more restrictions so that more heat can be extracted from the combustion gases. As efficiency increases, condensation of combustion gases within the vent system becomes more likely. Condensation of combustion gases should be avoided unless the system is specifically designed as fully condensing direct heating equipment.

Induced Draft (Fan Wall, Gravity Wall, Floor, Room, Hearth). Fan-assisted combustion systems for fan wall, gravity wall, floor, room, and hearth heaters can be designed with induced draft technology. Induced draft fans are located downstream of the combustion zone (at the exit of the heat exchanger) and regulate the amount of primary air at the burner resulting in a higher combustion efficiency. Induced draft systems also reduce off-cycle losses. Since induced draft fans are located at the exit of the heat exchanger, they tend to reduce off-cycle infiltration losses more than power burners. The induced draft fan essentially acts as a vent damper to prevent heated room air from being drawn into the vent system.

The space allocated for the draft hood is large enough to accommodate an induced draft fan. The induced draft fan could also be located anywhere along the length of the vent pipe as long as a draft can be maintained. Some installations may even incorporate a fan in the vent cap at the end of the venting system. Besides increasing AFUE, the steady-state efficiency will also increase because of the increasing amount of primary air to the burner. This increase is accomplished without further design modifications to the heater. Because the induced draft fan can be designed to overcome relatively large pressure drops within the heat exchanger, further increases in steady-state efficiency can be attained by redesigning the induced draft heat exchanger system. The heat exchanger can be redesigned to be more compact with more restrictions so that a greater amount of heat can be extracted from the flue gases. As efficiency increases, condensation of combustion gases within the vent system becomes likely. Condensation of combustion gases should be avoided unless the system is specifically designed as fully condensing direct heating equipment.

Two-Stage and Modulating Operation (Fan Wall, Gravity Wall, Floor, Room, Hearth). Two-stage or modulating operation allows fan wall, gravity wall, floor, room, and hearth heaters to meet heating load requirements more precisely. When low heating load conditions exist, the heater can operate at a reduced burner rate. This reduces cycling of the unit, which in turn, reduces large fluctuations in room temperature.

Two-stage or modulating burners attempt to reduce cycling of the heater by reducing the flow rate of gas at lower heating loads. These burners regulate gas flow but not air flow. Excess air is induced at lower gas flow rates, resulting in lower combustion efficiencies when compared to a normal or maximum gas flow rate. Because of this, heaters equipped with two-stage or modulating burners will always have a lower energy efficiency, as measured by the DOE test procedure, than heaters equipped with single-stage burners.

To overcome this lower efficiency and achieve efficient two-stage or modulating operation, an induced draft or forced draft system using a two-speed or variable speed combustion fan must incorporate the two-stage or modulating burner. With the multi-speed combustion fan, the excess air drawn into the burner at low gas flow rates can be reduced so that there is no decrease in the steady-state efficiency of the heater. The air-circulation fan on forced-air two-stage and modulating direct heaters must also be capable of two-stage or variable speed operation to avoid a similar decrease in energy efficiency.

Improved Fan or Blower Motor Efficiency (Fan Wall, Hearth). For fan wall and hearth heaters equipped with air circulation fans, the fan or blower motor efficiency can be increased to reduce the electrical energy consumption of the unit.

Typical fan motor sizes are 1/20 horsepower. Since the motor is so small, increased efficiency would yield extremely small electrical energy savings. Direct heating manufacturers typically use permanent split capacitor (PSC) fan motors. The next jump in motor efficiency would be a permanent magnet brushless DC (BLDC) motor. A brushless DC motor uses electronic controls to commutate the motor, eliminating brush friction and losses, and therefore increasing motor efficiency. BLDC motors also have longer lifetimes than electric motors containing brushes.

Increased Insulation (Floor). Floor furnaces are the only heater types installed directly in an unconditioned space. Floor furnaces are typically installed where the majority of the unit is below the subfloor of the first floor and in the crawlspace of a home. DOE considered increasing or improving the insulation of a heater only for this product class of DHE. Since room heaters and wall furnaces are installed in the conditioned space, insulation in the cabinet would only serve to minimize cabinet hot spots and reduce the amount of radiated heat coming off the heater. Additionally, the DOE test procedure calls for the measurement of jacket losses only for floor furnaces. Increased or improved insulation would reduce the jacket losses of this type of DHE and increase the overall AFUE. Insulation is installed in a floor furnace at the perimeter of the cabinet.

Condensing (Fan Wall, Gravity Wall, Floor, Room, Hearth). If fan wall, gravity wall, floor, room, and hearth heaters are designed to have high steady-state efficiencies, enough heat will be extracted from the combustion gases so that condensing will occur within the heat exchangers. This type of heater is typically termed a condensing heater and AFUEs generally exceed 90 percent. One typical condensing design uses a high efficiency fan-assisted combustion system with additional heat exchanger surface area.

This heater system can be designed to achieve high efficiencies that are much higher than non-condensing systems. In the power burner or induced draft technology option description, condensation of the combustion gases within the vent system was not desired. Since condensation is now desired, the fan-assisted system is designed to extract as much heat from the combustion gases as possible. Typically, condensing systems exhaust their combustion gases through a direct vent. Positive pressure can be maintained within the vent system to exhaust the low temperature combustion gases with a fan installed upstream of the combustion zone. Conversely, negative pressure can be maintain within the vent system to draw combustion gases from the combustion chamber with a fan installed downstream of the combustion zone. The combustion gases can be passed through a larger or improved heat exchanger to extract as much heat as possible. Condensing systems require some means to collect and drain the condensate that develops within the heat exchangers. Condensing systems can be designed to use secondary heat exchangers and air circulation fans as well.

Condensing Pulse Combustion (Fan Wall, Gravity Wall, Floor, Room, Hearth). If a fan wall, gravity wall, floor, room, or hearth heater is designed to have a high steady-state efficiency, enough heat will be extracted from the flue gases so that condensing occurs within the heat exchanger. This type of heater is typically termed a condensing heater and AFUEs generally exceed 90 percent. One typical condensing design uses pulse combustion with additional heat exchanger area.

This heater system can be designed to achieve very high efficiencies. In the power burner or induced draft technology option description, condensation of the combustion gases within the vent system was not desired due to the corrosive nature of the condensate. However, to achieve high AFUEs, enough heat must be extracted from the combustion gases to cause the combustion gases to condense. Condensing pulse combustion systems are designed to extract as much heat from the combustion gases as possible. Pulse combustion systems, like a direct-vent type heater, draw combustion air from the outside. Once ignition is accomplished, the pulse combustion process is self-sustaining. The turbulent nature of the pulse combustion process requires no mechanical devices (*e.g.*, induced draft fans or power burners) to vent the combustion products to the outside. Pulse combustion designs may use a secondary heat exchanger and an air circulation fan to increase steady-state efficiency. The secondary heat exchanger is usually located at the forced air blower outlet and before the combustion air enters the combustion chamber. Part of the efficiency gain comes from capturing the heat of vaporization of the combustion gases before they are expelled to the outside. Combustion gases condense because the temperature of the vented gases falls to about 130 °F. A condensate drain is usually needed to route the condensed moisture into a floor drain.

Air Circulation Fan (Floor, Room). Air circulation fans improve the steady-state efficiency of floor and room heaters by circulating air in a counter-current mode to the flow of combustion products. In gravity-type heaters, room air circulates co-current with the combustion products, driven only by the thermal buoyant forces. Counter-current heat exchangers are inherently more efficient than co-flowing types. In addition, the higher air flow rates that occur in forced-air heaters result in higher heat transfer coefficients than gravity-type heaters can achieve.

AFUE increases due to air circulation fans result solely from improving the steady-state efficiency of the heater. This technology is only considered for room heaters and floor furnaces. Air circulation fans are known to be easily incorporated into currently available room heater models as manufacturers already provide consumers with the option of purchasing fans for these units. Though floor furnaces do not currently have the option of adding a circulation fan, DOE believes the cabinet is large enough to incorporate a fan without having to enlarge the cabinet.

Sealed Combustion (Fan Wall, Gravity Wall, Floor, Room, Hearth). Fan wall, gravity wall, floor, room, and hearth heaters that pull air from the conditioned space to use for the combustion process waste heat. Removing energy in the form of heated air and exhausting it outside of the conditioned space is inherently less efficient than drawing outside air for the combustion process. Fan wall, gravity wall, floor, and room direct heating equipment with sealed combustion chambers prevents heat rejection from occurring. Using outside air for heating ensures that air within the conditioned space is not used for combustion.

Unlike sealed combustion heaters (which do not induce any pressure), non-sealed combustion heaters induce negative pressure during operation. When air is exhausted from a conditioned space, the removed air must be replaced to satisfy the induced pressure differential. This happens naturally by infiltration, or leaking, of cool outside air into the conditioned space. Sealed combustion does not contribute to exchanges of air between the interior conditioned spaces and exterior unconditioned spaces.

Sealed combustion provides inherent safety benefits. Sealing the combustion process prevents harmful combustion gases from mixing and accumulating in the conditioned space. Combustion products are exhausted outside the space.

3.3.2.3 Pool Heaters

The following technology options could improve the efficiency of pool heaters:

1. Electronic ignition
2. Improved heat exchanger design
3. More effective insulation (combustion chamber)
4. Power venting
5. Sealed combustion
6. Condensing pulse combustion
7. Condensing

Electronic Ignition. One of the most common ways to reduce energy consumption of pool heaters is to eliminate the standing pilot light as a method of igniting the main burner. Pool heater manufacturers already make heaters with electronic ignition and many different variations in models are available. Since February 1984, California has required that pool heaters use electronic ignition instead of standing pilot lights. Three electronic ignition devices are used in gas-fired pool heaters:

Intermittent Pilot Ignition. This device lights a pilot by generating a spark, which in turn lights the main burner.

Intermittent Direct Ignition. This system lights the main burner directly by generating a spark.

Hot Surface Ignition. This system lights the main burner directly from a sufficiently hot surface.

Unlike standing pilot ignition systems that consume gas continuously, these devices operate only at the beginning of each on-period. Although there is no increase in the steady-state efficiency when using electronic ignition devices, the overall fuel consumption is reduced. Pool heater pilot lights typically consume approximately 1,100 Btu/hr on average.

Improved Heat Exchanger Design. Pool heaters are currently capable of reaching the steady-state efficiency level where potentially damaging condensation will start to form on the heat exchanger. A small increase in heat exchanger size may be possible without causing condensation of the combustion gases by increasing the heat exchanger surface area. The burner configuration might also require adjustment. No blower would be required for this technology option.

The heat exchanger size can also be increased while preventing condensation from forming by using a governor. The governor maintains pool water temperature and water flow to prevent condensation of combustion gases. The governor limits the efficiency of the heat exchanger so that the latent heat of the combustion gases is not transferred to the pool water. At least one manufacturer makes a pool heater with a condensing governor.

If condensation is desired to achieve a high steady-state efficiency, then the pool heater design must properly manage and dispose of the potentially damaging condensate. This can be accomplished with corrosion-resistant materials and a condensate drain.

More Effective Insulation (Combustion Chamber). Combustion chambers for pool heaters are insulated with fiberglass blankets to prevent heat loss through the walls of the combustion chamber to the exterior of the pool heater. Manufacturers reduce the amount of heat loss to increase the thermal efficiency by using materials with more effective insulation properties. Pool heater manufacturers currently produce products that use Fiberfrax panels and refractory tiles to reduce the amount of heat loss through the combustion chamber walls. By lining the sides and bottom of the heat exchanger with these materials, manufacturers increase the amount of heat that is transferred from the combustion chamber to the heat exchanger. DOE identified several manufacturers that use insulation that is more effective than fiberglass blankets for pool heater combustion chambers.

Power Venting. Fan-assisted combustion systems for pool heaters can be designed with power venting technology. Induced draft fans located downstream of the combustion zone (at the exit of the heat exchanger) or forced draft fans located upstream of the combustion zone (at the entrance to the combustion chamber) regulate the amount of primary air at the burner resulting in a higher combustion efficiency.

To increase the energy efficiency, a larger heat exchanger surface area (which increases the heat transfer rate) is required. The larger heat exchanger typically increases the amount of restriction to the air flow path and the combustion gases are typically not buoyant enough to provide adequate draft. Therefore, the power vent forces combustion gases through the restricted heat exchanger area. Forcing the air increases turbulence, which increases the rate of heat transfer. The increased rate of heat transfer will in turn increase steady-state efficiency and energy efficiency. Configuration of other parts of the pool heater, such as the combustion chamber and burner, can remain constant with this technology option. However, additional alterations of the heat exchanger may be needed if condensing occurs, which can corrode the heat exchanger.

Sealed Combustion. Pool heater combustion processes require a regulated ratio of fuel to air to be efficient. The primary air for the combustion chamber must be supplied at a constant rate without any fluctuations. To maintain a specific supply of primary air, manufacturers seal the combustion chamber of the pool heater. Manufacturers produce pool heaters with seal combustion chambers and air intakes that operate at consistent energy efficiency levels regardless of outside conditions. Pool heaters, particularly those installed outdoors, without seal combustion chambers are susceptible to reductions in thermal efficiency in high winds. Pressure and air flow variations caused by ambient conditions can vary the amount of primary air supplied to the burners, which can reduce burner efficiency. Several manufacturers produce pool heaters with sealed combustion chambers.

Condensing Pulse Combustion. To increase the energy efficiency of a pool heater, the water vapor in the combustion gases must be condensed to capture the heat of vaporization. The heat exchanger must be altered for condensing operations to prevent the acidic condensate from corroding the heat exchanger. A condensate drain is also required.

Condensing can be accomplished by using pulse combustion burners. These burners operate with self-sustaining resonating pressure waves that alternately ratify the combustion chamber (causing a fresh fuel/air mixture to enter the chamber) and pressurize it (causing ignition by compression of the mixture to its flash point). This process is initiated by a blower that supplies the initial fuel and air mixture to the chamber. The fuel and air mixture is ignited with a spark igniter. Once resonation is established, the process becomes self-sustaining. Pulse combustion systems feature high heat transfer rates through the heat exchanger due to increased turbulence of combustion gases. High-efficiency gas-fired boilers using pulse combustion are currently available.

Condensing. To increase the efficiency of a pool heater, the water vapor in the combustion gases must be condensed in order to capture the heat of vaporization. The heat exchanger must be altered for condensing operations to prevent condensate from corroding the heat exchanger. A condensate drain is also required.

This technology option uses a radiant burner, a modified heat exchanger to condense the combustion gases, and a burner located above the heat exchanger to prevent corrosion from contact with condensate. A ceramic matrix radiant burner is located above a series of finned heat exchanger tubes. A blower forces an air and gas mixture through the ceramic matrix burner and down past the heat exchanger. Most of the heat is radiated to the heat exchanger. By locating the burner above the heat exchanger and out of the way of any condensation, the burner does not require corrosion protection. The heat exchanger must still be corrosion-resistant, however, and a condensate drain must be installed.

3.3.3 Technologies That Do Not Affect Energy Efficiency as Measured

DOE reviewed the technologies presented in the previous assessment and considered their impacts on DOE's test procedure results as well as their impacts on energy use. Since EF, AFUE, and thermal efficiency are the relevant performance metrics in this rulemaking, DOE did not consider the technologies discussed in section 3.3.2 that have no effect on EF, AFUE, or thermal efficiency during the screening analysis. However, DOE does not discourage manufacturers from using these technologies because they might reduce annual energy consumption. In this section, DOE explains why these technologies do not affect EF, AFUE, or thermal efficiency.

3.3.3.1 Water Heaters

The following technology options either do not effect or do not increase the EF of residential water heaters: timer controls, self-cleaning, intelligent controls, and modulating controls.

Timer Controls (Electric). Timer controls affect the time of day when the elements of an electric storage water heater may be energized. This feature has the potential to reduce energy use because the water in the tank remains at a reduced temperature for part of the day.[52] These savings are achieved because the electric consumption, in response to the standby losses, is shifted from on-peak to off-peak times when electricity costs less.

However, the DOE test procedure for electric storage water heaters does not show the effects of timer controls because the test specifies normal operation for the water heater during the entire testing period. Additionally, this technology affects the energy consumption pattern of the water heater and not energy efficiency because load is shifted, not reduced. The typical use of the average consumer is specified by the test procedure, and time of day and conditions of an electrical supply grid (on-peak or off-peak) are not factors. Although this technology can reduce peak energy demand and reduce overall energy costs to the consumer throughout the year, it does not increase EF under the DOE test procedure for electric storage water heaters because of the specified test conditions. Therefore, DOE does not consider timer controls as a technology for improving EF of electric storage water heaters.

Self Cleaning (Gas, Oil, Electric Storage). Self-cleaning incorporates a method to introduce the inlet water at high turbulence so that the sediment occurring naturally in the water remains in suspension and does not settle to the bottom of the tank. Additionally, a self-cleaning dip tube unseats sediment that accumulates during long standby periods. Tank cleaning does not improve EF as measured by the DOE test procedure. The test procedure to determine EF is 24 hours, and testing immediately follows manufacture. Sediment build-up can reduce EF over the life of the water heater, but the amount of build-up that could occur in a 24-hour period, if any, would not be enough to affect the test results. This technology facilitates the removal of deposits, which can build up over the life of a water heater, which is typically 9 to 15 years. Deposits decrease water heater performance, reduce tank volume, and can cause leaks. Self-cleaning improves tank life and reduces the required maintenance, but these are not determinants for EF. Therefore, DOE does not consider self-cleaning as a technology for improving EF of electric, gas, or oil storage water heaters.

Intelligent Controls (Gas, Oil, Electric Storage). Intelligent controls and self-diagnostics minimize energy consumption and maximize hot water output. Several storage and instantaneous type water heaters currently on the market include self-diagnostics and electronic controls. Typically, varying the temperature of the heated water based on the household demand minimizes energy consumption. However, the DOE test procedure has a set draw pattern and usage for the water heater, and specifies an inlet and outlet temperature for the water. As a result, there is no opportunity for varying temperatures to affect the EF calculation. Consequently, DOE does not consider intelligent controls as a technology for improving EF of electric storage, gas storage, and gas instantaneous water heaters.

Modulating Controls (Instantaneous). Modulating water heater controls can reduce energy consumption, improve energy efficiency, and improve overall performance by changing the operating conditions in response to household demand. Modulating controls can also reduce output so that excess energy is not wasted when only small temperature differentials or low flow rates need to be satisfied. Although modulating controls can increase energy efficiency over a broad operating range, they do not affect EF as measured by the DOE test procedure. Due to the specified test conditions, (*i.e.*, no variability in demand or delivery), there is no opportunity for varying operating conditions to affect the EF calculation. Therefore, DOE does not consider modulating controls as a technology for improving EF of instantaneous water heaters.

3.3.3.2 Direct Heating Equipment

DOE has not identified any technologies that do not affect or do not increase AFUE for residential direct heating equipment as measured by DOE's test procedure.

3.3.3.3 Pool Heaters

Only one technology option has no effect on the thermal efficiency of residential pool heaters: electronic ignition.

Electronic Ignition. Electronic ignition (intermittent pilot, intermittent direct, and hot surface ignition) reduces the energy consumption of gas-fired pool heaters by eliminating the standing pilot. Pool heater pilot lights burn continuously with a burn rate ranging from 1,000 Btu/h to 2,000 Btu/h during the pool heater operating season. Electronic ignition uses energy only when there is a call for heating and only until a flame has been established.

Electronic ignition can be used to replace the standing pilot and reduce the overall energy consumption of the pool heater. However, the thermal efficiency descriptor specified by EPCA and measured by DOE's test procedure, does not take into account the energy efficiency benefits of ignition sources that are alternatives to standing pilots (*e.g.*, electronic ignition). The thermal efficiency descriptor, as measured by the DOE test procedure, does not account for additional energy consumption of a continuous, standing pilot light when the burner is off because it is a steady-state test procedure and thermal efficiency is determined when the burner is on. That is, thermal efficiency only captures energy efficiency impacts that affect combustion and the transfer of energy to the water. The thermal efficiency descriptor does not account for any energy that a pool heater may use in the standby period. Therefore, standards expressed in terms of this descriptor cannot require use of such alternative ignition sources or capture the full energy savings benefit of their use. Therefore, DOE does not consider electronic ignition as a technology for improving thermal efficiency for pool heaters.

REFERENCES

1 U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey, 2005 Consumption and Expenditures Tables, Water-Heating Consumption Tables*, 2005. Washington, DC.

2 AHRI. About AHRI. Last accessed March 09, 2010. <http://www.ahrinet.org/Content/AboutARI_31.aspx>.

3 AHRI. About AHRI: What We Do. Last accessed March 09, 2010. <http://www.ahrinet.org/Content/WhatWeDo_29.aspx>

4 HPBA. HPBA Overview. Last accessed March 09, 2009. <www.hpba.org/index.php?id=46>.

5 The Association of Pool and Spa Professionals.About Us. Last accessed March 09, 2010. < http://www.apsp.org/aboutus.aspx>.

6 "*Who's Who in the North American Appliance Industry,*" *Appliance Magazine,* September 2007.

7 "The Share-of-Market Picture for 2008," *Appliance Magazine*, September 2009.

8 Ibid.

9 U.S. Small Business Administration, *Table of Small Business Size Standards Matched to North American Industry Classification System Codes*, October 1, 2007. Washington, DC. Last accessed April 16, 2009. <www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf>.

10 Northwest Energy Efficiency Alliance. *Assessment of the Residential Water Heater Market in the Northwest*, July 13, 2006. Portland, Oregon. Last accessed April 16, 2009. <www.nwalliance.org/research/reports/06-158.pdf>.

11 Ibid.

12 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for Consumer Products: Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Water Heaters Including: Market and Technology Assessment. January 17, 2001. Washington, D.C. Last accessed April 16, 2009. < www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/03.pdf>

13 *Appliance Magazine*, "56th Annual Statistical Review," May 2009.

14 Northwest Energy Efficiency Alliance. *Assessment of the Residential Water Heater Market in the Northwest*, July 13, 2006. Portland, Oregon. Last accessed April 16, 2009. < www.nwalliance.org/research/reports/06-158.pdf>.

15 California Energy Commission. *2007 Appliance Efficiency Regulations*, December 29, 2007. Sacramento, CA. Last accessed April 16, 2009. <www.energy.ca.gov/2007publications/CEC-400-2007-016/CEC-400-2007-016-REV1.PDF>.

16 Ibid.

17 Ibid.

18 Ibid.

19 Ibid.

20 Ibid.

21 Ibid.

22 Natural Resources Canada. Guide to Canada's Energy Efficiency Regulations. Last accessed April 16, 2009. <www.oee.nrcan.gc.ca/regulations/guide.cfm?text=N&printview=N>

23 Ibid.

24 Secretaria de Energia. *Eficiencia termica de calentadores de agua para uso domestico y commercial. Limites, metodos de prueba y etiquetado*, September 1, 2000.

25 American Council for an Energy-Efficient Economy. Last accessed April 16, 2009. <www.aceee.org/about/about.htm>.

26 Consortium for Energy Efficiency. Last accessed April 16, 2009. <www.cee1.org/cee/about.php3>.

27 ENERGY STAR®, Water Heater Criteria Development. Last accessed April 11, 2008. <www.energystar.gov/index.cfm?c=new_specs.water_heaters>.

28 Federal Energy Management Program. Last accessed April 17, 2009. <www1.eere.energy.gov/femp/about/index.html>.

29 Federal Energy Management Program. Last accessed April 17, 2009. <www1.eere.energy.gov/femp/procurement/eep_gas_waterheaters.html>.

30 Federal Energy Management Program. Last accessed April 17, 2009. <http://www.eere.energy.gov/femp/procurement/eep_electric_waterheaters.html>.

31 Pacific Gas and Electric Company. Energy Efficiency Rebates. Last accessed April 17, 2009. <http://www.pge.com/includes/docs/pdfs/shared/saveenergymoney/rebates/08_residential_appliance.pdf>.

32 Central Florida Gas. Natural Gas Conservation Rebates. Last accessed April 17, 2009. <http://www.cfgas.com/index.cfm?fuseaction=residential.rebateshomes>.

33 City, Water, Light, and Power. Energy Rebates. Last accessed April 20, 2008. <http://www.cwlp.com/energy_services/ESO_services_programs/water_heater_reb.htm>

34 Austin Energy. Residential Energy Efficiency Rebate Program, Last accessed April 17, 2009. <http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=TX30F&state=TX&CurrentPageID=1&RE=1&EE=1>.

35 Super Efficient Gas Water Heating Appliance Initiative. Last accessed April 17, 2009. <http://www.segwhai.org/>

36 U.S. Census Bureau. 2006. "Table Q1. New Privately Owned Housing Units Started in the United States by Purpose and Design." New Residential Construction, November 2006. Last accessed April 17, 2009. <http://www.census.gov/const/www/quarterly_starts_completions.pdf>.

37 Ibid.

38 U.S. Census Bureau. Last accessed April 17, 2009. <http://www.census.gov/cir/www/>.

39 Ibid.

40 Stanonik, F. A. *AHRI Heating Products Data Submission*. Air Conditioning, Heating, and Refrigeration Institute, Arlington, VA. March 12, 2008.

41 Ibid.

42 Ibid.

43 Hearth, Patio, and Barbeque Association. HPBA US Hearth Statistics. Last Accessed June 12, 2009. <http://www.hpba.org/statistics/hpba-us-hearth-statistics>.

44 Ibid.

45 GAMA. GAMA Product Directories. Last accessed March 17, 2008. <http://www.gamanet.org/gama/inforesources.nsf/vAllDocs/Product+Directories?OpenDocument>.

46 California Energy Commission. Last accessed March 17, 2008. <http://www.energy.ca.gov>.

47 Lawrence Berkeley National Laboratory. *Gas Filled Panels.*, Last accessed March 17, 2008. <http://gfp.lbl.gov/applications/default.htm>.

48 American Council for an Energy-Efficient Economy. *Consumer Guide to Home Energy Savings: Condensed Online Version.,* Last accessed March 17, 2008. <http://www.aceee.org/consumerguide/waterheating.htm>

49 Enhanced, Compact and Ultra-Compact Heat Exchangers: Science, Engineering and Technology. *Development of a New Type Heat Exchanger for Natural Refrigerant CO_2 Heat Pump Water Heaters.* Last accessed March 17, 2008. <http://www.r744.com/knowledge/papers/files/pdf/pdf_190.pdf>.

50 IEA Heat Pump News Letter. Volume 24, No. 3/2006. Last accessed March 17, 2008. <http://www.heatpumpcentre.org/publ/HPCOrder/ViewDocument.aspx?RapportId=396>.

51 American National Standards Institute, *Gas Water Heaters, Volume 1: Storage Water Heaters with Input Ratings of 75,000 Btu per Hour or Less*, 1993. New York, NY. Report No. ANSI/AGA Z21.10.1-1993.

52 Energy Efficiency and Renewable Energy. *Install a Timer and Use Off-Peak Power for Electric Water Heaters.* Last accessed March 19, 2008. <http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13110>.